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Dundalk Sewershed Evaluation Study Plan
Project No. 1047

Sewershed Study and Plan – Final Report
Sanitary Sewer Overflow Consent Decree
Civil Action No. JFM-02-1524

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Executive Summary

The City of Baltimore entered into a Consent Decree (CD), on September 30, 2002, with the United States Environmental Protection Agency (EPA), the State of Maryland Department of the Environment (MDE), and the Department of Justice (DOJ). The objective of Paragraph 9 of the CD was to complete a series of "Collection System Evaluation and Sewershed Plans". This Sewershed Study and Plan details the evaluation of the Dundalk Sewershed, one (1) of eight (8) sewersheds within in the City of Baltimore.

The Dundalk Sewershed is located on the south eastern corner of the City of Baltimore, below Outfall Sewershed and adjacent to Low level Sewershed. This sewershed is approximately 17.2 square miles, with about 3.9 square miles within the City of Baltimore and the remaining portion in Baltimore County. The City portion of the Dundalk Sewershed serves residential areas with approximately 9,647 people, and a combination of commercial and heavy industrial facilities.

The Collection System within the Dundalk Sewershed includes approximately 152,000 linear feet (LF) of pipe ranging in diameter from 8 to 66 inches, 600 manholes, and one pump station. The sewerage from the sewershed flows to the Dundalk Pump Station and then discharges to a large interceptor in the Outfall sewershed before being conveyed to the Back River Wastewater Treatment Plant (WWTP) for treatment and disposal.

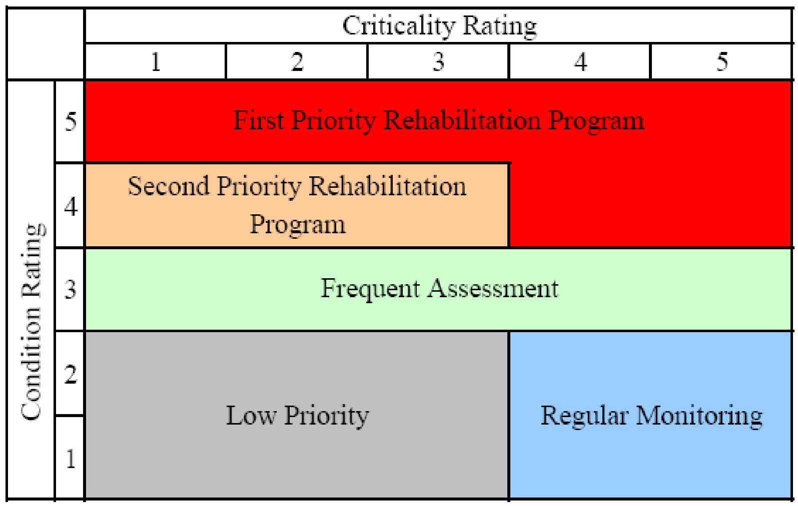
As required in the CD, each of the following elements are addressed in this Plan:

- Presentation of the results of the rainfall and flow monitoring, as well as smoke and dyed-water testing, conducted in the sewershed.
- Identification of all deficiencies discovered during the collection system inspections, which included inspection of all gravity sewers having a diameter of eight inches or greater using closed circuit television (CCTV) inspection and complete the inspection of all manholes and other appurtenances.
- Identification of all rehabilitation and other corrective actions taken, or proposed to be taken, to address the deficiencies identified during the evaluation of the sewershed.
- Description of the decision-making criteria used to select future corrective action.
- Proposition of a plan and schedule for future evaluation of the collection system within the sewershed.
- Proposition of a plan and schedule for implementing rehabilitation and other corrective actions determined necessary either to correct deficiencies identified during the collection system evaluation or to ensure operation of the collection system without causing or contributing to an SSO.
- Proposition of a plan and schedule for eliminating those physical connections between the sanitary sewer collection system and the storm water collection system.
- Determination of the range of storm events for which the collection system in its existing condition can convey peak flows without the occurrence of SSOs.
- Determination of the range of storm events for which the collection system will be able to convey peak flows without the occurrence of SSOs assuming completion of the Paragraph 8 construction projects and completion of the proposed rehabilitation and other corrective action projects recommended in this Sewershed Plan.
- Certification of the Geographic Information System (GIS) described in Paragraph 14 of the CD.

There were no Paragraph 8 construction projects in the Dundalk Sewershed to evaluate the effectiveness of any SSO elimination project. However, as required by the CD, this Sewershed Study and Plan identifies specific improvements and corrective actions needed to address;

- Deficiencies and aid in reducing rainfall dependent inflow and infiltration (RDII) contributing to SSOs,
- Deficiencies identified during the hydraulic analyses,
- Other deficiencies that contribute to SSOs.

As part of the sewershed study, the City developed a condition and criticality protocol that provides the framework for a rehabilitation strategy based on criticality (consequence of failure) and condition (probability of failure) rating of 1 through 5. Assets whose failure can impact the community or environment and whose condition is the poorest received a higher rating and will receive attention sooner. Assets that receive a lower rating will receive some level of regular monitoring but no immediate action or rehabilitation. Five levels of prioritization were developed based on the combination of condition and criticality as shown in the following matrix:



Prioritization of asset rehabilitation projects and other corrective actions was developed with consideration that all proposed improvements required to eliminate SSOs must be completed before January 1, 2016, as stipulated by the CD.

The proposed improvements include completing inspection of manholes and sewer that could not be inspected during this study, rehabilitation of "First and Second Priority Rehabilitation Program" manholes and sanitary sewers, and required hydraulic improvements. The proposed improvement projects and the estimated costs in 2008 dollars to complete these repairs are summarized in the following tables:

Dundalk Sewershed Study and Plan: Proposed Improvement Projects Summary						
1st and 2nd Priority Improvement Budget						
Item	Manhole	Sewer Pipes				Total Cost
	Rehab / Replacement	CIPP Lining (LF)	Point Repair (LF)	Point/CIPP Repair (LF)	Replacement (LF)	
1st Priority	3	15,430	50	40 / 322	1,178	$5,936,253
2nd Priority	12	2,217	0	280 / 845	0	$563,073
Total	**15**	**17,647**	**50**	**320 / 1,167**	**1,178**	**$6,499,326**

Dundalk Sewershed Study and Plan: Proposed Improvement Projects Summary			
Estimated Hydraulic Improvement Budget (2 Year Storm)			
Item	Rehabilitation Method	Quantity	Cost
DU06 and DU07			
8" - 12" Pipe	CIPP	7129 (LF)	$467,522
Manholes	Rehab/Replacement	33	$174,272
		Total Cost	**$641,794**

Dundalk Sewershed Study and Plan: Proposed Improvement Projects Summary			
Estimated Manhole and Sewer Inspection Budget			
Item	Inspection Method	Quantity	Cost
Manholes	Inspection	55	$77,610
Sewers	CCTV	15,400 (LF)	$109,340
		Total Cost	**$186,950**

The manholes and sewers that received higher condition and criticality rating scores were recommended for inclusion in the First and Second Priority corrective action plan. These repairs included the rehabilitation or replacement of 15 manhole structures and over a total 20,362 LF of deteriorated sewer pipes located throughout the sewershed.

The recommended hydraulic improvements based on a 2-year design storm include an extensive inflow and infiltration (I/I) reduction program on sections of pipe and manholes located on Dundalk Avenue and Chandlery Street in basins DU06 and DU07. The First and Second priority manholes and sewer pipes in DU06 and DU07 that are also recommended for hydraulic improvements are only accounted for in the hydraulic improvements and not duplicated in the First and Second priority manholes and Sewer improvement budget. The recommended manhole and sewer inspection project will include inspection of any manholes and sewers that could not be inspected during this study followed with rating of their physical conditions.

In accordance with Paragraph 9 of the CD, the City will also implement several continuous data collection programs in order to assess the effectiveness of the rehabilitation and other operation and maintenance enhancement efforts within the sewershed. These programs will be comprehensive, system-wide initiatives that will include a long-term flow monitoring plan, a sewer cleaning program, CCTV and manhole inspection programs and root and grease control programs.

The interrelationship between the City's eight (8) sewersheds, known as boundary conditions, must be carefully considered before significant hydraulic repairs are completed. Six (6) sewersheds are connected and hydraulically interdependent, creating "boundary" conditions that must be defined and considered for hydraulic modeling. The City has begun development of a system-wide model that will be refined and improved as the individual sewershed studies complete calibration of their respective models. This Plan provides recommended improvements that should be implemented by the City in accordance with the schedule provided. However, the Plan should not be considered final and may require amendment once the system-wide hydraulic model is completed and simulations are performed.

1.0 Project Description

1.1 Project Background

The City of Baltimore entered into a Consent Decree (CD), on September 30, 2002, with the United States Environmental Protection Agency (EPA) and the State of Maryland Department of the Environment (MDE). The objective of Paragraph 9 of the CD was to complete a series of "Collection System Evaluation and Sewershed Plans". This Sewershed Study and Plan details the evaluation of the Dundalk Sewershed, one (1) of eight (8) sewersheds in the City of Baltimore.

As required in Paragraph 9 of the CD, each of the eight (8) sewersheds in the City will be studied by a sewershed consultant with emphasis on the inspection of sanitary sewers 8 inches and larger in diameter, including all sewer structures. The City provided guidance and general direction to the sewershed consultants to assure that all tasks completed in support of the study are prepared in a standardized format to facilitate the collection and review of the data for compliance with the requirements of the CD. The engineering firm, RJN Group, Inc. was tasked with the study and evaluation of the Dundalk Sewershed.

The Dundalk Sewershed is a approximately 17.2 square miles, with about 3.9 square miles within the City of Baltimore and the remaining portion located in Baltimore County.

The Dundalk Sewershed Study and Plan began August 2007 under Project No. 1047. The plan generally consists of inspection and characterization of the sewage collection system as defined by the CD. This includes flow monitoring, collection of rainfall data, manhole inspection, closed circuit television (CCTV) inspection, smoke testing, dyed-water testing, updates to the City's GIS based sewer mapping system, analysis of complaint data, projections of current and future base sanitary flow (dry weather), preparation, calibration, and validation of a hydraulic model, identification of critical sewer system components, condition assessment and criticality rating, formulation of a long term rehabilitation and corrective action plan, preparation of cost estimates, and preparation of the sewershed plan.

The structure of this Sewershed Study Report has been established by the Baltimore Sewer Evaluation Standards (BaSES) Manual, to address each of the elements defined in the CD Paragraph 9.C, summarized below:

i. An evaluation of the effectiveness of completed and proposed projects using rainfall and flow monitoring data and the hydraulic model
ii. Identification of deficiencies discovered during inspections
iii. Identification of rehabilitation and other corrective actions taken to address deficiencies
iv. Identification of rehabilitation and other corrective actions proposed to be taken
v. Description of decision making criteria for selection of future corrective action
vi. Plan and schedule for implementation of rehabilitation and other corrective action found necessary to correct deficiencies
vii. Preparation of a prioritization scheme applied to rehabilitation projects
viii. Preparation of cost estimate for proposed rehabilitation and other corrective action
ix. Preparation of a plan and schedule for eliminating physical connections between sanitary sewer and storm drains
x. Determination of range of storm events for which existing collection system can convey peak flows without occurrence of sanitary sewer overflows (SSOs)
xi. Identification of model components that have the potential to cause or contribute to overflows
xii. Determination of the range of storm events for which peak flows can be conveyed without occurrence of SSOs once the recommended construction projects are in place

xiii. Presentation of the results of rainfall and flow monitoring conducted in the sewershed
xiv. Description of the quality assurance and quality control analyses performed for data collected
xv. Description of the smoke and dye testing performed
xvi. Quantification of inflow and infiltration (I/I) and identification of sources of the I/I
xvii. Description of additional data collection activities that will continue after completion of rehabilitation and corrective action
xviii. Certification that the GIS system is functional in accordance with Paragraph 14.B of the CD

1.2 Sewershed History and Previous Studies

Dundalk has a history of being an industrial area of Baltimore. The industrialization of this area began in 1893, when Henry McShane built a bell foundry off the Patapsco River along with a grand summer vacation home. The McShane foundry also manufactured piping and plumbing fixtures.

The railroad line followed the foundry to the area in 1895 and the foundry became a rail depot. When railroad officials asked the McShanes to choose a name for the railroad stop, William James McShane, Henry's son and the vice-president of the foundry, chose the name Dundalk, after his father's hometown in Ireland. The town of Dundalk was born with only a few farming families to claim as residents.

In 1916, Dundalk had 62 homes, one church and two stores. In that same year, Bethlehem Steel bought the Sparrows Point plant from the Maryland Steel Company, forming a large steel industry. The steel giant created the Dundalk Company, which purchased 1,000 acres of land near McShane's railroad stop.

The Dundalk Company hired E.H. Bouton, designer of Roland Park, to create a workingmen's Roland Park, one of the country's first planned communities. The community was planned in the new residential style excluding businesses except at specific spots and leaving land for developing schools, playing fields, and parks. It was designed to be close enough to the Plant for workers to commute to work, but far enough away to escape the noise of the mills. The Company helped increase the shipping and railroad industries in the area and was the basis for industrial and residential growth in Dundalk.

In 1859, the Baltimore Sewerage Commission was established to address flooding and pollution concerns. This Commission developed a policy to keep the sanitary and storm drain systems separate and in 1860, began construction of a storm drainage system. In 1906, the state of Maryland prohibited the City of Baltimore from discharging sewage into the Chesapeake Bay and its tributaries.

By 1911, the Back River Wastewater Treatment Plant (BRWWTP), where Dundalk wastewater is treated, began operation, and fifteen years later, the City had laid approximately 1200 miles of sewer pipes leading to the plant. In the late 20th century, upgrades were made to the BRWWTP, however, repairs to the sewer system were not addressed.

Over the years, numerous studies have been performed within the City by multiple engineering consultants. These include system-wide studies dating back to the 1980's, to more recent studies and hydraulic evaluation projects of specific sections of the entire city's collection system. These studies were reviewed and considered in the preparation of this report.

1.3 Purpose of Sewershed Study

The Dundalk Sewershed Study is part of the City of Baltimore's compliance with the Clean Water Act and Title 9, Subtitle 3 of the Environment Article, Annotated Code of Maryland and the regulations promulgated thereunder, and all terms and conditions of the Back River and the Patapsco NPDES Permits. This study evaluated the Dundalk sewer system for any overflows, illegal stormwater or sewer connections, and rainfall dependent inflow and infiltration (RDII) sources on public sewers and service laterals. Potential RDII sources on public sewers and service laterals have been identified through an extensive smoke and dyed water testing program. The evaluation and elimination of all overflows were carried out according to the measures set forth by Paragraph 8 through 15 of the CD. In addition, the City's GIS has been updated for the Dundalk area and is accurate, fully functional, and capable of displaying the information described in Paragraph 14.B.i through 14.B.iv of the CD.

1.4 Description of the Sewershed and Basins

The Dundalk Sewershed, as Shown in Figure 1.4.1, is located in the southeastern corner of the City of Baltimore. As shown in Map 1.5.1 is bounded by Eastern Avenue to the north, Inner Harbor to the south, Baltimore City/Baltimore County line (Central Avenue) to the east, and Newkirk Avenue to the west. Interstate 95 runs along the northwest border of the sewershed.

The Dundalk Sewershed has a population of approximately 71,953 people and covers 17.2 square miles of City of Baltimore and Baltimore County. The Dundalk Sewershed in the City is approximately 3.9 square miles in size with about 149,000 linear feet (LF) of gravity sewer ranging in diameter from 8 to 66 inches, 600 manholes, one pump station, and 4,000 LF of 36-inch diameter force main. The City portion of the Dundalk Sewershed serves approximately 9,647 people, and serves a combination of residential and commercial properties including heavy industrial facilities. The entire area drains to the Dundalk Pump Station, which then discharges to the Outfall Sewershed, before being treated at the City's Back River WWTP.

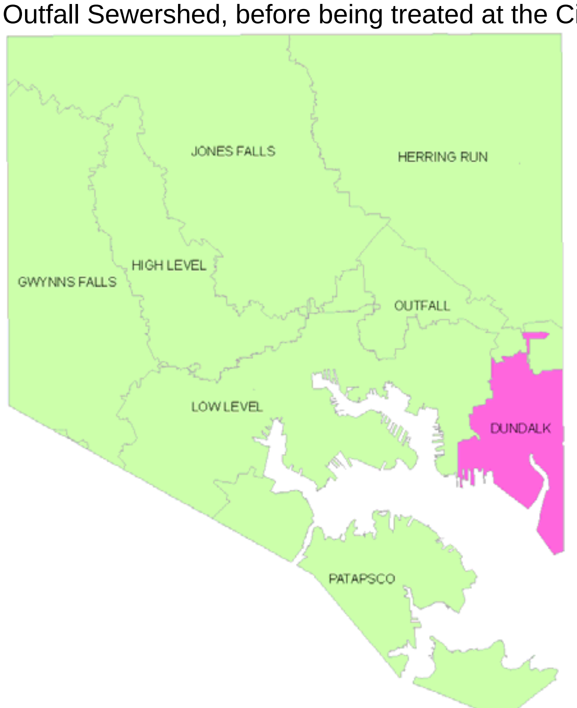


Figure 1.4.1: Location of Sewershed in the City

The Dundalk Sewershed within the City of Baltimore consists of eight basins identified as DU01, DU02, DU03, DU04, DU05, DU06, DU07, and TSDU03. Basins DU05, DU06, and DU07 collect wastewater from four major basins in the Baltimore County region of the Dundalk Sewershed. The four basins in Baltimore County are BDU01, BDU02, BDU03, and BDU04. The boundaries for each of the basins along with the pump station and major sewer lines are shown in **Map 1.5.1.** Brief descriptions of each of the basins located within the City's portion of the Dundalk Sewershed are as follows:

Basin DU01

Basin DU01 is located in the southwestern corner of the Dundalk Sewershed, bounded by Holabird Avenue to the north, Inner Harbor to the south, Newkirk Avenue to the west, and Broening Highway to the east. This basin is approximately 740 acres in size with 32 manholes and 14,700 linear feet (LF) of pipe. DU01 is an industrial basin with heavy industrial properties such as Canton Industrial Area and Holabird Industrial Park. Basin DU01 receives flows from basin DU02 and then discharges to the Dundalk Pump Station. The flow exiting DU01 was measured by a flow meter located on Broening Highway.

Basin DU02

Basin DU02 is located in the western part of the Dundalk Sewershed, bounded by O'Donnell Street to the north, Holabird Avenue to the south, Newkirk Street to the west, and Broening Highway to the east. Approximately 250 acres in size with 67 manholes and 16,900 LF of pipe, this basin covers a combination of industrial and commercial areas with a small residential portion. Basin DU02 receives flows from Basin DU03 and discharges to Basin DU01. The flow exiting DU02 was measured by a flow meter on Newkirk Street.

Basin DU03

Basin DU03 is located in the northwestern corner of the Dundalk Sewershed, bounded by Pratt Street to the north, O'Donnell Street to the south, Newkirk Street to the west, and Gusryan Street to the east. This basin is approximately 200 acres in size with 97 manholes and 21,100 LF of pipe. DU03 covers primarily residential areas with approximately 2,500 people. In addition, a few municipal properties (e.g., schools and government agencies) and Mt. Carmel Cemetery exist in this basin. Basin DU03 discharges into basin DU02 and the flow exiting this basin was measured north of O'Donnell Street.

Basin DU04

Basin DU04 is located in the middle of the Dundalk Sewershed, bounded by Cardiff Avenue to the north, Beckley Street to the south, Broening Highway to the west, and Imla Street to the east. Approximately 180 acres in size with about 65 manholes and 13,500 LF of pipe, this basin covers a combination of industrial and commercial properties. DU04 discharges to the Dundalk Pump Station and the flow exiting this basin was measured north of Edgewater Street.

Basin DU05

Basin DU05 is located in the southeastern corner of the Dundalk Sewershed, bounded by Beckley Street to the north, Inner Harbor to the south, Broening Highway to the west, and Baltimore City/Baltimore County line to the east. Approximately 450 acres in size with about 76 manholes and 18,200 LF of pipe, this basin covers a combination of industrial, commercial, and residential properties. DU05 receives flows from basins DU06, BDU03 and BDU04, and discharges to the Dundalk Pump Station. The flow exiting DU05 was measured by a flow meter on Edgewater Street.

Basin DU06

Basin DU06 is located in the eastern part of the Dundalk Sewershed, bounded by Cardiff Avenue to the north, Beckley Street to the south, Imla Street to the west, and Baltimore City/Baltimore County line to the east. This basin is approximately 170 acres in size with about 112 manholes and 25,100 LF of pipe. DU06 covers a combination of industrial, commercial, and residential properties with approximately 1,500 people. Basin DU06 receives flows from basins DU07 and BDU01, and discharges to basin DU05. The flow exiting DU06 was measured by a flow meter on Dundalk Avenue.

Basin DU07

Basin DU07 is located in the northeastern corner of the Dundalk Sewershed, bounded by Eastern Avenue to the north, Cardiff Avenue to the south, Gusryan Street to the west, and Baltimore City/Baltimore County line to the east. This basin is approximately 300 acres in size with about 116 manholes and 25,500 LF of pipe. DU07 covers primarily residential properties with approximately 3,400 people. In addition, other properties including St Stanislaus Cemetery are in this basin. Basin DU07 receives flows from County basin BDU02 and discharges to basin DU06. The flow exiting this basin was measured by a flow meter on Dundalk Avenue.

Basin TSDU03

Basin TSDU03 collects flow from all other basins and joins the Outfall Sewershed at the northern most point in the Dundalk Sewershed. The majority of this basin consists of the 54 to 66-inch diameter gravity sewer and some additional small diameter connections along its route. The basin contains 35 manholes and 14,000 LF of pipe. The flow exiting this basin which captures the entire Dundalk Sewershed was measured by a flow meter on Lombard Street.

1.5 Collection System Components

The components of the Dundalk collection system included in the sewershed evaluation consist of: gravity sewers with diameter of 8 inches or greater, a pump station, force mains, and manholes along the sewer lines.

Dundalk Gravity Interceptors

This section provides a brief description of the gravity interceptors (gravity sewers with diameter of 10 inches or greater) located within each metered basin. The interceptor and major sewer boundaries for each basin are shown in Map 1.5.1.

DU01 Interceptor

The DU01 interceptor is located in a highly industrial area of the Dundalk Sewershed. The south end of the DU01 interceptor runs parallel with Broening Highway until it reaches Keith Avenue. The northern section of the interceptor runs south on South Newkirk Street and then heads directly east along Keith Avenue where it joins the previously mentioned line at the intersection of Keith Avenue and Vail Street. The interceptor continues east to the Dundalk Pump Station. This interceptor ranges from 15 to 42 inches in diameter and is approximately 14,200 LF.

DU02 Interceptor

This interceptor begins at manhole S63M__005MH on O'Donnell Street, and heads south towards Cardiff Avenue, then continues west to run parallel with Cardiff Avenue. The interceptor goes under I-95 and I-895, then moves south along South Ponca Street. It then heads west towards South Newkirk Street where it continues south before discharging into the DU01 interceptor. This interceptor section ranges from 10 to 33 inches in diameter and is approximately 7,800 LF.

DU03 Interceptor

Beginning at manhole S65G__011MH on Eastern Avenue, this interceptor moves west along Eastern Avenue and then south running parallel to Umbra Street. As this interceptor passes Foster Avenue, another section of interceptor joins and expands to 18 inches in diameter. The interceptor then continues south and discharges into the DU02 interceptor. This interceptor ranges from 10 to 18 inches in diameter and is approximately 5,000 LF.

DU04 Interceptor

Two (2) sections of this interceptor run toward each other along Holabird Avenue and meet at manhole S67U__016MH at the intersection of Holabird Avenue and Charlotte Avenue. The interceptor continues south, crossing Seaforth Street and Beckley Street, and then joins a 36-inch interceptor from basin DU05 on Edgewater Avenue before discharging to the Dundalk Pump Station. This interceptor ranges from 10 to 15 inches in diameter and is approximately 4,700 LF.

DU05 Interceptor

At the south end of the DU05 basin, this interceptor starts just south of Riverview Avenue. It then heads northwest along Ralls Avenue and continues along Edgewater Street before joining a 15-inch interceptor from basin DU04. At the north end of the DU05 basin, the interceptor runs south parallel with Dundalk Avenue and then heads southwest until the intersection of Pine Avenue and Oak Avenue. It then heads south on Oak Avenue, then west on Detroit Avenue and connects with the other end of the interceptor at Edgewater Street. BDU03 and BDU04, basins in the County, discharge into the DU05 interceptor. This interceptor ranges from 10 to 36 inches in diameter and is approximately 7,900 LF.

DU06 Interceptor

This interceptor moves south along Dundalk Avenue and then heads southwest and discharges into the DU05 interceptor. BDU01, a basin in the County part of the sewershed, discharges into the DU06 interceptor. This interceptor section ranges from 10 to 27 inches in diameter and is approximately 5,600 LF.

DU07 Interceptor

The interceptor begins at manhole S67I__004MH at the intersection of Dundalk Avenue and Gusryan Street, and then moves south along Dundalk Avenue until it discharges into the DU06 interceptor. BDU02 also discharges into the DU07 interceptor. This interceptor section ranges from 10 to 24 inches in diameter and is approximately 9,500 LF.

TSDU03 Interceptor

The TSDU03 interceptor begins at manhole S67S__019MH at the intersection of Charlotte Avenue and Danielle Avenue where the Dundalk Pump Station force main discharges into a 54-inch gravity sewer. The 54-inch diameter gravity interceptor heads north, crossing Cardiff Avenue and Boston Street before reaching O'Donnell Street. The interceptor continues north on Gusryan Street where the 54-inch interceptor expands to a 66-inch diameter interceptor. The 66-inch diameter interceptor heads north and joins a 147-by-132 inch diameter interceptor in the Outfall Sewershed. The 54 to 66-inch interceptor in TSDU03 is approximately 8,700 LF.

Dundalk Pump Station

The Dundalk pump station is located on Broening Highway near the intersection of Broening Highway and Keith Avenue and was constructed in the 1940's. A rehabilitation project on the pump station was completed in August 2005. The rehabilitation included replacing the existing four pumps with new pumps having variable frequency drives and controls, replacing existing valve actuators with electrical actuators, replacing the existing three generators with a 1,000kW generator, and installing a new control system. The design capacity of the station is approximately 33 MGD.

Dundalk Force Main

The Dundalk force main is made of cast iron pipe and is 4,000 feet long beginning at the Dundalk Pump Station and ending at manhole S67S__019MH at the intersection of Charlotte Avenue and Danville Avenue. The 36-inch diameter force main section leaves the pump station and heads east then north, crossing Beckley Street, Seaforth Street, and Holabird Avenue until the intersection at Charlotte Avenue and Danville Avenue, where it discharges to a 54-inch gravity sewer in TSDU03.

2.0 Effectiveness of Paragraph 8 Construction Projects

There were no Paragraph 8 Projects in the Dundalk Sewershed.

3.0 Flow Monitoring Program

3.1 Overall Description

To fully understand the dynamics of the sewage collection system, the City of Baltimore completed a comprehensive City-wide rainfall and flow monitoring program. The program consisted of installing flow meters within the City's collection system and rain gauges throughout the City and County of Baltimore.

An initial comprehensive program the City executed consisted of installing over 350 flow monitors City-wide and collecting data for 12 months, from May 2006 to May 2007. Twelve of these meters were within the Dundalk Sewershed, four (4) of which were located along the City-County boundary line, to measure the amount of flow coming from the County. The monitors measured depth and velocity, from which flows were calculated at five minute intervals. In addition to the flow monitors, 20 rain gauges were installed City-wide with some gauges installed outside of the City limits. All 20 rain gauges were utilized in conjunction with generated radar rainfall for analysis.

This comprehensive program was designed to evaluate infiltration and inflow (I/I) at an average density of one (1) meter for every 25,000 linear feet of pipe. Using wireless remote data collection, the program achieved an overall 97% data uptime, exceeding the 90% uptime required by the Consent Decree (CD). Furthermore, the program achieved 9% inferred, or "qualified" data, meaning that, on average the meters collected both a depth and a velocity measurement 91% of the time.

Sufficient dry and wet weather flow data was collected during the initial 12-month comprehensive program. Consequently, the city-wide flow monitoring network was reduced to approximately 100 meters (deemed long-term meters) in May 2007. These long-term meters will be used for continuous system assessment and model calibration, and have remained in service for over two (2) years, exceeding the CD requirement of at least 18 months of flow monitoring under Paragraph 9.E.iii.b.

3.2 Metering Network within the Dundalk Sewershed

There were 12 sites within the Dundalk Sewershed selected for flow monitoring. All of the sites were used for I/I evaluation and the calibration of the hydraulic model. Table 3.2.1 lists the meters and their primary purpose and installation history. Using the City's Geographic Information System (GIS), the monitoring sites for I/I evaluation were selected at a meter density of approximately one (1) for ever 25,000 linear feet (LF) of sewer pipe.

Map 3.2.1 depicts the location of the meters, rain gauges, and ground water gauges within the sewershed. Figure 3.2.1 is a flow schematic of the meter network within the Dundalk Sewershed. Site reports that show manhole identities, hydraulic assessments, proposed equipment, details on installation arrangements, manhole dimensions, pipe shape, location coordinates and special considerations such as safety and traffic control are provided in Attachment 3.2.1.

Independent depth and velocity measurements (field confirmations or calibrations) were taken across the full range of depths during dry and wet weather conditions throughout the project duration. Flow monitor performances were also assessed relative to these measurements, and necessary adjustments were made to the equipment to maximize the accuracy of the data with respect to actual conditions.

Table 3.2.1

Dundalk Sewershed Study and Plan: Flow Monitoring Program

Flow Meter Purpose and Installation History

Meter	Basin	Purpose	Installation History	
			Installation Date	Removal Date
DU01	DU01	I/I Evaluation and Model Calibration	3/31/2006	5/20/2007
DU02	DU02	I/I Evaluation and Model Calibration	1/19/2006	5/20/2007
DU03	DU03	I/I Evaluation and Model Calibration	3/7/2006	5/20/2007
DU04	DU04	I/I Evaluation and Model Calibration	4/6/2006	5/19/2007
DU05	DU05	I/I Evaluation and Model Calibration	1/9/2006	5/20/2007
DU06	DU06	I/I Evaluation and Model Calibration	1/9/2006	5/19/2007
DU07	DU07	I/I Evaluation and Model Calibration	1/18/2006	5/19/2007
BDU01	BDU01	I/I Evaluation and Model Calibration	1/18/2006	Long Term
BDU02	BDU02	I/I Evaluation and Model Calibration	1/18/2006	Long Term
BDU03	BDU03	I/I Evaluation and Model Calibration	2/29/2008	Long Term
BDU04	BDU04	I/I Evaluation and Model Calibration	2/29/2008	Long Term
TSDU03	6301 Lombard	I/I Evaluation and Model Calibration	6/17/2006	Long Term

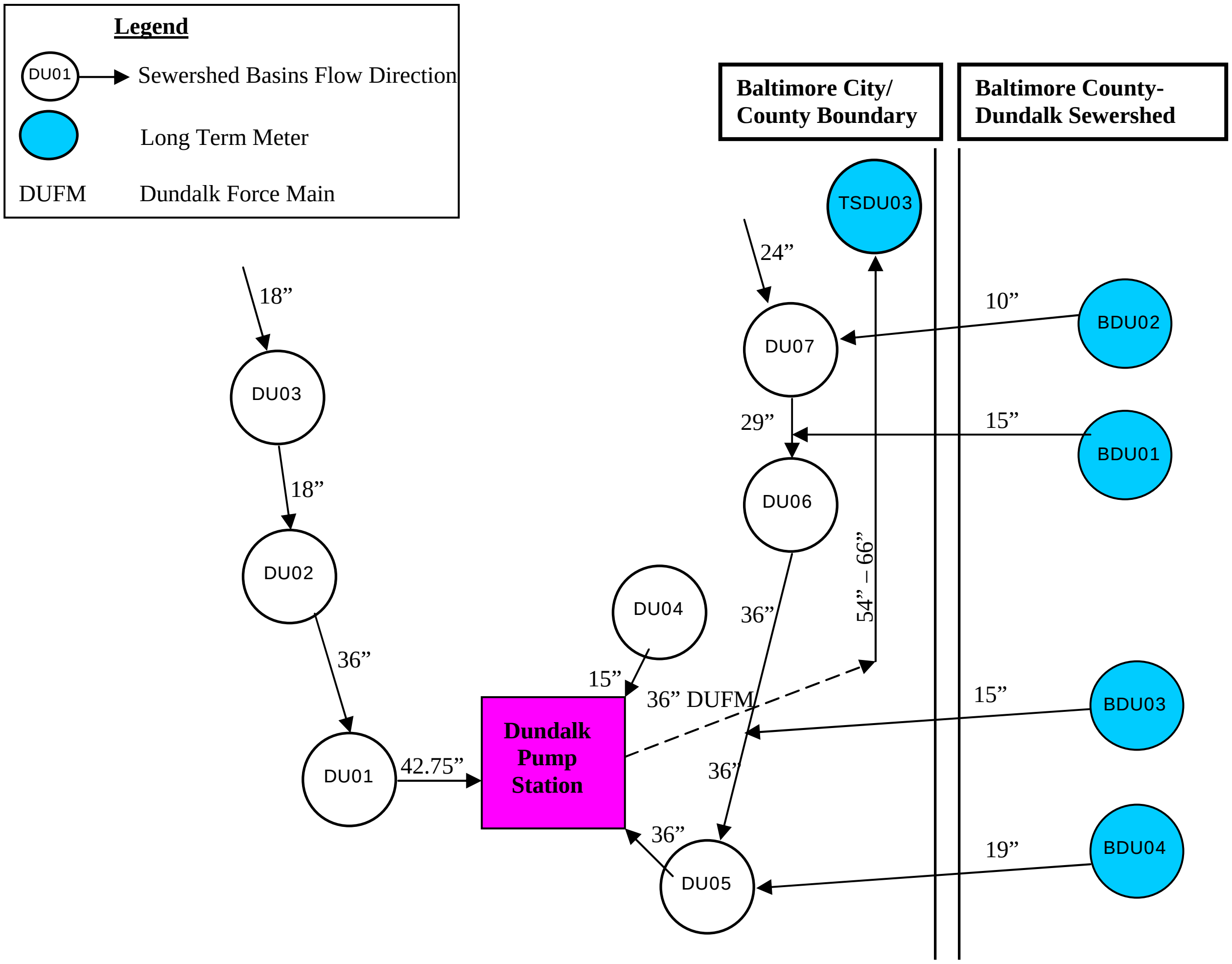


Figure 3.2.1: Dundalk Sewershed Flow Monitoring Schematic

3.3 Rainfall Measurement

RJN, under a separate contract, measured the contribution from rainfall to all sewersheds within the City's jurisdictional boundaries. This was performed using a network of 20 rain gauge stations with a minimum coverage of one (1) rain gauge per ten (10) square miles, as well as data compiled by Doppler radar utilizing a minimum resolution of one (1) pixel per four (4) square kilometers. To measure the contribution from rainfall occurring in portions of the collection system outside Baltimore City limits, RJN installed additional rain gauges to be shared between Baltimore City and Baltimore County. **Figure 3.3.1** shows the rain gauge network for Baltimore City and Baltimore County.

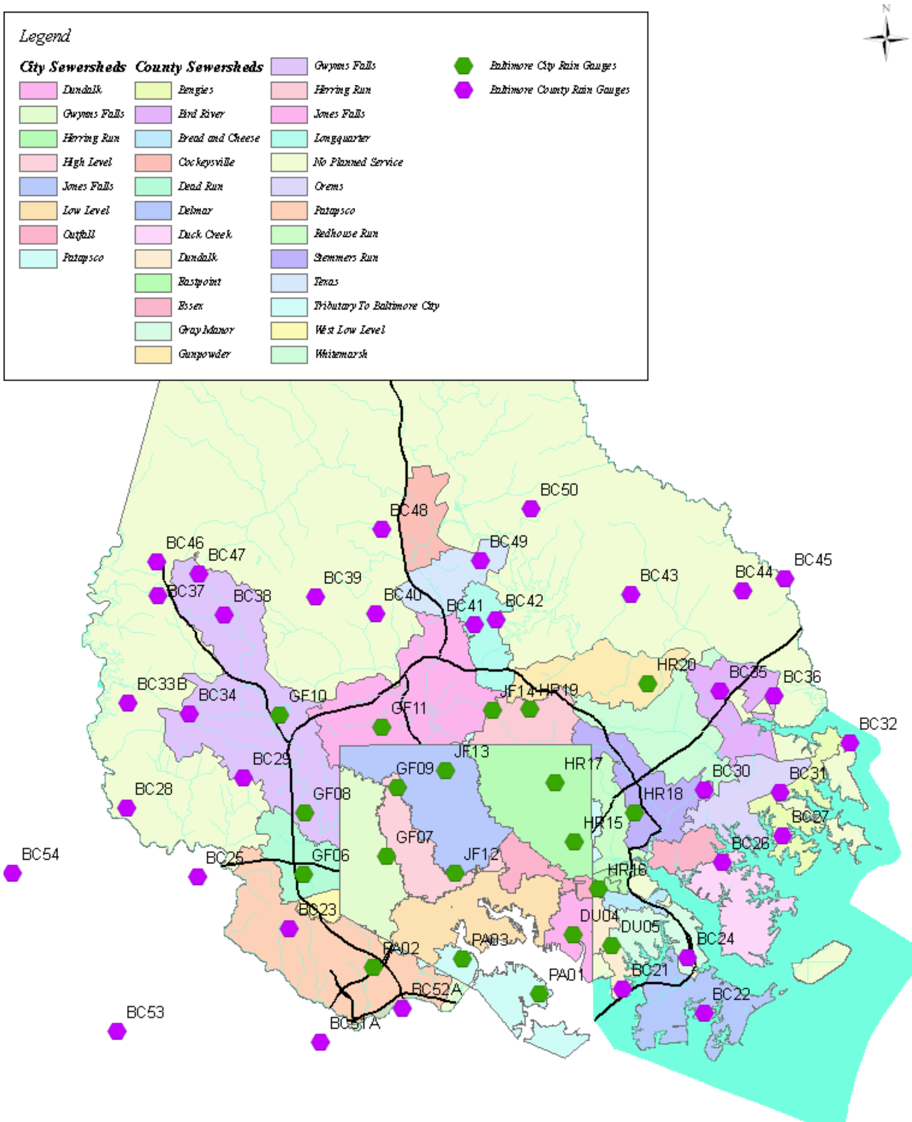


Figure 3.3.1: Rain Gauge Network

3.4 Doppler Radar Analysis

In accordance with the requirements of the CD, the City performed Doppler Radar Rainfall Analysis in conjunction with rain gauges at a resolution of one (1) gauge for every ten (10) square miles. RJN, under a separate contract, performed these services for the City using the CALAMAR software platform. CALAMAR is a tool used to study the hydraulic impacts of precipitation through a combination of radar images and a network of rain gauges installed over a geographic area. CALAMAR uses three databases: a radar image database, a rain gauge database, and a geographical database. CALAMAR was used to process each recorded rainfall event with an average total depth of greater than 0.5 inches of rain.

After collecting the rain gauge network data and the radar images, CALAMAR produces a model that provides geographically accurate, integrated rainfall intensity data for any predefined area. The Baltimore City geographical area was divided into one square kilometer pixels, and for every significant rain event, Doppler radar rainfall images were generated for every pixel within the Back River and Patapsco wastewater treatment plant service areas. There were a total of 29 storms captured and identified for use in the study during the primary flow monitoring period between May 2006 and May 2007. The dates of those storm events and the event details are listed in **Table 3.4.1**.

Table 3.4.1

Dundalk Sewershed Study and Plan: Flow Monitoring Program

Storm Selected for Doppler Radar Analysis

Rainfall Event	Time of Peak Intensity	60-min Peak Intensity (in/hr)	Total Duration (hr:min)	Total Rain (in)
Thursday, May 11, 2006	7:45:00 PM	4.080	9:50	1.23
Sunday, May 14, 2006	12:05:00 AM	0.960	1:45	0.37
Friday, June 02, 2006	10:20:00 PM	2.880	1:30	1.18
Monday, June 19, 2006	3:30:00 PM	0.960	0:10	0.22
Saturday, June 24, 2006	8:05:00 PM	0.240	2:40	0.36
Sunday, June 25, 2006	8:55:00 PM	2.520	22:20	6.71
Wednesday, July 05, 2006	10:40:00 PM	1.920	5:50	2.17
Saturday, July 22, 2006	6:15:00 PM	2.040	5:20	0.84
Friday, September 01, 2006	8:00:00 PM	0.480	28:55	3.02
Tuesday, September 05, 2006	8:20:00 AM	1.320	13:55	1.82
Thursday, September 14, 2006	4:45:00 AM	0.720	16:50	1.71
Thursday, September 28, 2006	5:40:00 PM	1.920	4:15	0.80
Thursday, October 05, 2006	9:30:00 PM	0.480	1:55	1.73
Tuesday, October 17, 2006	10:30:00 AM	0.360	7:40	0.79
Friday, October 20, 2006	12:35:00 AM	0.840	8:30	0.64
Saturday, October 28, 2006	5:30:00 AM	2.640	16:45	2.01
Wednesday, November 08, 2006	3:55:00 AM	0.600	15:00	1.47
Thursday, November 16, 2006	4:00:00 PM	3.120	47:45	2.06
Wednesday, November 22, 2006	4:30:00 PM	0.240	8:30	1.03
Friday, December 22, 2006	11:50:00 PM	0.360	14:20	1.05
Monday, December 25, 2006	12:55:00 PM	0.240	10:10	0.6
Sunday, December 31, 2006	4:30:00 AM	0.840	14:10	1.06
Sunday, January 07, 2007	7:55:00 PM	0.240	8:10	0.8
Thursday, March 01, 2007	4:05:00 AM	0.360	22:45	0.85
Thursday, March 15, 2007	5:20:00 PM	0.360	23:55	2.69
Friday, March 23, 2007	3:30:00 PM	0.120	17:50	0.35
Wednesday, April 04, 2007	5:10:00 AM	1.200	5:15	0.77
Wednesday, April 11, 2007	2:50:00 AM	0.600	7:35	1.17
Saturday, April 14, 2007	4:10:00 AM	0.240	31:10	2.92

3.5 Data Collection, Data Processing, and QA/QC Process

The City required the use of a host software support application program for remote wireless data collection of all flow meters, rain gauges, and ground water gauges. The host software maintained clock synchronization with the host system's clock for all field remote terminal units (RTUs), thus insuring time interval integrity for all collected data. A system employing client/server architecture, capable of storing all project deliverables including flow and rainfall data, equipment configurations, event logs, and site parameters into a SQL database was utilized. The software allowed any networked computer (with the appropriate access rights) to access the data stored in the SQL database using a common web browser (e.g. Microsoft Internet Explorer). The web module was "read only" in order to protect data integrity, and had the ability to present near-real time data. Field data measurements could be forwarded to the server immediately following collection by the field RTUs, and the server could immediately post the data to the web site for viewing by authorized parties.

Trained data analysts experienced in processing and analyzing flow and rainfall data for sanitary sewer systems used various analytical tools, such as hydrographs and scattergraphs to verify the accuracy of the measured flow data. Flow balancing methods were also used to verify the accuracy and precision of the flow data. Data collection was performed remotely at least twice (2) a week and was scheduled in a manner to allow data review by a trained data analyst within 24-hours of the data collection. The analyst assessed any maintenance or monitor performance issues, and a crew was dispatched within 48 hours, and the issue resolved within 72 hours from the time the issue was identified. All measurements, adjustments, and efforts undertaken during site visits were logged in an installation/maintenance log specific to that installation.

Qualified field crews visited each monitor installation as appropriate, to perform any necessary maintenance to the equipment. As stated above, field crews were dispatched within 48 hours and any operation and maintenance (O&M) issue was resolved within 72 hours from the time the issue was identified. The amount of time a meter collected usable data is referred to as "uptime." Any time when the meter was not collecting usable data is referred to as "downtime." All flow monitoring services provided were required to maintain a 90% uptime for all meters throughout the monitoring period. A monthly uptime table was submitted to the City to demonstrate compliance with the uptime requirement.

3.6 Dry Weather Analysis

Dry weather analysis was used to generate base sanitary flow and base groundwater infiltration quantities for the Dundalk Sewershed basins. For the complete Dundalk I/I Evaluation Report, see **Attachment 3.8.1** provided on the CD at the end of this report.

3.6.1 Base Infiltration (BI) Rates and Severity

The complete analysis for base infiltration estimated during weekday summer dry weather is provided in **Table 3.6.1,** found on page 3-8**.** The analysis considered both gross flows and net flows, when indicated, for each site. Gross values include any upstream meter basins, while net values represent only the data measured within the meter basin and excluding any upstream meter basins. For sites with incoming flow that was measured at another meter upstream, a net flow computation was performed. This balancing of flows was performed to insure that the individual meter results were reasonable relative to each other. Net flows represent only the flows within a meter basin not previously measured by any other upstream meter.

The acronyms for **Table 3.6.1** are defined as follows:

- A_{gross} – Entire drainage area contributing to the meter, including upstream meter basins.
- A_{net} – Net area draining to the meter, excluding any upstream meter basins.
- IDM – Inch-Diameter-Mile is a parameter used to evaluate infiltration severity. It is calculated by summing the product of pipe length (in miles) times pipe diameter (inches) for all sewer pipes in the meter basin.
- ADF – Average Dry-weather Flow represents the average flow measured during dry-weather conditions in millions of gallons per day, and includes groundwater infiltration. The "gross" includes entire drainage area, while "net" excludes flow measured at upstream basins.
- Q_{net}/Q_{gross} – This is the ratio of the net average dry weather flow to gross average dry weather flow.
- WWP – Wastewater Production represents the estimated sanitary flow generated strictly from human activities during dry-weather conditions in millions of gallons per day, and excludes groundwater infiltration. Net flow excludes that from upstream meter basins.
- BI_{net} – Base Infiltration (net) represents the average groundwater leaking into the sanitary sewer pipes during dry-weather conditions in millions of gallons per day, excluding base infiltration from upstream meter basins.
- BI Severity – This is the net base infiltration in gallons per day divided by the inch-diameter-miles of pipe within the meter basin.
- BI Rate – This is the ratio of net base infiltration to net average daily flow expressed as percent.
- WWP Rate – This is the ratio of the net wastewater production in gallons divided by the linear footage of pipes within the meter basin.

Table 3.6.1

Dundalk Sewershed Study and Plan: Flow Monitoring Program

Dry Weather Analysis - Summer 2006 - Weekdays Only

Basin	A_{gross} (acres)	A_{net} (acres)	A_{net}/A_{gross} (%)	IDM (in-dia-mile)	ADF_{gross} (MGD)	ADF_{net} (MGD)	Q_{net}/Q_{gross} (%)	WWP_{net} (MGD)	BI_{net} (MGD)	BI Severity (gpd/idm)	BI Rate (%)	WWP Rate (gln/l.f.)
DU01	1233	739	59.9	109.8	0.764	0.084	11.0	0.083	0.001	9.1	1.2	2.9
DU02	494	289	58.4	49.1	0.698	0.095	13.6	0.091	0.004	81.5	4.2	4.4
DU03	206	206	100.0	38.3	0.603	0.603	100.0	0.276	0.327	8537.9	54.2	11.3
DU04	152	152	100.0	31.0	0.271	0.270	99.6	0.074	0.196	6322.6	72.6	3.7
DU05	2345	445	19.0	65.9	3.327	0.274	8.2	0.266	0.008	121.4	2.9	11.6
DU06	775	167	21.6	53.9	1.160	0.471	40.6	0.272	0.199	3692.0	42.3	9.7
DU07	463	263	56.9	55.0	0.438	0.290	66.2	0.171	0.119	2163.6	41.0	5.7
BDU01	145	145	100.0	36.4	0.251	0.251	100.0	0.107	0.144	3956.0	57.4	4.9
BDU02	199	199	100.0	42.6	0.148	0.148	100.0	0.078	0.070	1643.2	47.3	2.9
BDU03	272	272	100.0	91.4	0.826	0.826	100.0	0.366	0.460	5032.8	55.7	6.5
BDU04	853	853	100.0	206.2	1.069	1.069	100.0	0.441	0.627	3040.7	58.7	3.5

To compare base infiltration (BI) severity among basins of different sizes, a unit infiltration rate was calculated based on peak infiltration. The size of a meter basin is defined by the tributary length and corresponding pipe diameters and the pipe lengths were derived from the GIS data provided by the City. To determine basin size relative to others, each basin was measured by inch-diameter-mile (IDM). The BI rates were then normalized by IDM to provide a more accurate picture of the severity in each basin. The percentage of the average daily flow (ADF) that was due to BI was also calculated.

Based on the normalized BI rates, the basin ranking from highest severity to lowest severity is: DU03, DU04, DU06, DU07, DU05, DU02, and DU01. The worst basin, DU03, had BI severity of 8,564 gallons per day (gpd) per IDM, followed by DU04 and DU06, with 6,322 gpd per IDM, and 3,692 gpd per IDM, respectively. The total BI rate for the Dundalk Sewershed within Baltimore City is 0.86 MGD. **Map 3.6.1** shows the severity of the base infiltration in the Dundalk Sewershed.

3.6.2 Correlation with Completed CCTV and Manhole Inspections

CCTV and manhole inspections were used to rate all the sewers and manholes on a scale of 1 through 5 with 5 being the worst. As a result of these ratings, basins DU03, DU05, and DU06 were recommended for further inspection using smoke testing. There was some correlation between the CCTV and manhole inspections and the dry weather analysis, as the results from the dry weather analysis shows the worst basins were DU03, DU04, and DU06.

3.6.3 Influence of Groundwater Table on Infiltration Rates

A comparison of the winter dry day data and the summer dry day data was performed to determine the influence of the groundwater table on infiltration rates. The infiltration rates for winter dry days are typically higher than those for summer dry days. Therefore, as the groundwater table rises so do the infiltration rates. The groundwater table level is affected by climate changes and by the amount of groundwater used by vegetation. Therefore the groundwater table will vary both with the seasons and from year to year. During the winter the groundwater table is higher primarily due to the low water demand by vegetation and soils become saturated with water. In the summer, conditions reverse; as vegetation increases and water demands increase, the soils become dry and the groundwater table lowers.

3.6.4 Base Infiltration (BI) from Baltimore County

The BI analysis in Section 3.6.1 does not reflect the BI contributions from Baltimore County. There are four basins in the County that contribute to the flows in the city portion of the Dundalk Sewershed, these basins are BDU01, BDU02, BDU03, and BDU04, shown in Table 3.6.1. All four of these basins contribute approximately 1.3 MGD of BI to Baltimore City and the total Dundalk Sewershed BI rate becomes 2.2 MGD. The County contributes approximately 60% of the total BI for the Dundalk Sewershed.

3.7 Wet Weather Analysis

Wet weather analysis was used to quantify the rainfall dependent infiltration and inflow (RDII) in the Sewershed basins. RDII calculations were conducted through Sliicer.com. Sliicer is a tool developed by ADS Environmental Services, Inc. to find the locations of the worst I/I problems in a sanitary sewer collection system using rainfall and flow data. For the complete Dundalk I/I Evaluation see the report provided in **Attachment 3.8.1**.

3.7.1 Observed Peak Flows

Peak flows for each storm were provided by the flow metering data. Based on observation of the flow meter records, the peak flows in each basin follow approximately 1 hour behind the peak rainfall of a storm event. This data is shown on the hydrographs provided in the Dundalk I/I Evaluation Report.

3.7.2 Rain Dependent I/I (RDII) Rates and Severity

Normalizing the RDII is extremely important when comparing results to find the worst RDII basins. The most raw wet weather flow does not necessarily lead to the right conclusion about the location of the worst I/I problems in the collection system. The raw I/I information needs to be correlated with basin size and rainfall information before it becomes useful.

Each basin's RDII value was normalized by linear foot of pipe and inches of rain (lf/in-of-rain). Based on these calculations the basins were ranked from most severe to least severe RDII in the following order: DU06, DU01, DU03, DU07, DU04, DU05 and DU02. DU06 had the highest amount of RDII of 22 gallon per linear feet per inch of rain (Gal/lf/in-of-rain). DU02 had the least amount of RDII of 3.9 Gal/lf/in-of-rain. Table 3.7.1 shows a complete list of RDII values and capture coefficients for each basin. The RDII in the Dundalk Sewershed within the City is approximately 78 Gal/lf/in-of-rain. Map 3.7.1, located at the end of this section, shows the RDII basin rankings for the Dundalk Sewershed.

Table 3.7.1

Dundalk Sewershed Study and Plan: Flow Monitoring Program

Wet Weather Analysis Table

Basin	RDII (Gal/lf./in-of-rain)	Winter Capture Coefficient, R (%)	RDII Ranking	Winter Capture Coefficient (R) Ranking
DU01	14.84	2.14	2	6
DU02	3.90	1.02	7	7
DU03	13.00	5.55	3	2
DU04	7.60	3.62	5	4
DU05	5.95	2.88	6	5
DU06	22.00	13.45	1	1
DU07	10.29	4.33	4	3
BDU01	20.27	11.16	N/A	N/A
BDU02	5.13	2.59	N/A	N/A
BDU03	5.20	3.93	N/A	N/A
BDU04	4.50	2.50	N/A	N/A

Note: RDII and Capture Coefficient of DU05 are normalized to the total area and linear footage of DU05, BDU03, and BDU04

In addition to pipe size, each basin's RDII value was normalized by basin area. This normalized value is called the winter capture coefficient, R, and represents the percentage of the volume of rain water that fell on the basin and entered the collection system. In order to calculate the capture coefficient, plots of Q versus i were made. Q is the calculated I/I for a storm and i is the corresponding rainfall. The slope of the regression line is termed S. The winter capture coefficient was then calculated using the following equation:

R = (36.83 (acres-in/mg) * S (mg/in)) / Area (acres)

Based on these calculations the basin ranking from most severe to least severe is: DU06, DU03, DU07, DU04, DU05, DU01, and DU02. DU06 had the highest normalized RDII at 13.4 % rainfall, while DU02 had the lowest amount of normalized RDII at 1.02 % rainfall. See Table 3.7.1 for complete list of rankings. Q vs. i plots for each flow meter are included in the Dundalk I/I Evaluation Report in Attachment 3.8.1.

The scattergraphs from the Dundalk I/I Evaluation were reviewed to assess the hydraulic performance of the collection system. Based on the data, DU02, DU03 and DU04 do not pose surcharge or backwater problems. However, basins DU01, DU05, DU06, and DU07 show potential surcharge or backwater conditions. The County basins that contribute to the City's I/I rates generally do not demonstrate as high of surcharge conditions as the City basins. BDU02 and BDU03 do not show any significant surcharge or backwater conditions, while BDU01 and BDU04 show some surcharge or backwater conditions.

3.7.3 Correlation with Completed CCTV and Manhole Inspections

Based on the wet weather analysis, the areas with possible capacity issues and sanitary sewer overflows (SSOs) are DU05, DU06, and DU03. These basins all show I/I rates of greater than 10 Gal/lf/in-of-rain. CCTV inspections were performed on all pipes 8 inches in diameter and larger. The CCTV inspections verified that there were significant amount of leaks in these basins causing the high RDII values.

Although, manhole inspections showed that DU02 had the highest number of manholes in need of immediate rehabilitation, this basin does not have high RDII. Therefore, it is likely that the main source of the modest infiltration in DU02 is deteriorated pipes as opposed to deteriorated manholes. Based on the low RDII, it is expected that pipes in this basin would require minimal rehabilitation.

3.7.4 RDII from Baltimore County

The RDII was also calculated for the four basins in the Baltimore County portion of the Dundalk Sewershed based on meter data and GIS linear footage. These basins contribute approximately 35 Gal/lf/in-of-rain of RDII. When this is added to the RDII within the City, 78 Gal/lf/in-of-rain, the total RDII for Dundalk Sewershed is approximately 113 Gal/lf/in-of-rain. Therefore, the County contributes approximately 31% of the total RDII for all of Dundalk Sewershed.

3.7.5 Smoke Testing Recommendations

Based on the RDII evaluation, basins DU06, DU03, and DU07, had I/I rates significantly greater than 10 Gal/lf/in-of-rain, making them potential areas for capacity issues and

SSOs. The CCTV and manhole inspections also confirmed these findings. Therefore, smoke testing was recommended for each of these basins. In addition, based on CCTV results in other residential areas, residential sections of DU02 and DU04 were also recommended for smoke testing.

Although DU01 exhibited I/I rates greater than 10 Gal/lf/in-of-rain, this basin consists primarily of large diameter interceptor sewers and, therefore, is not believed to have capacity issue and was not recommended for smoke testing.

The City approved the smoke testing recommendations and all smoke testing was completed in September 2008. Section 4.4 of this report provides more information on the smoke testing results.

3.8 Dundalk Infiltration and Inflow (I/I) Evaluation Report

For the complete I/I evaluation, see the Dundalk I/I evaluation report in Attachment 3.8.1. The report was submitted to the City and approved in October 2008. The report contains site reports, scattergraphs, hydrographs, and Q versus i plots for every flow monitoring location.

4.0 Sewer System Evaluation Study

4.1 Overall Description

The Dundalk Collection System Evaluation and Sewershed Plan, City of Baltimore Project No. 1047 consists of a wide range of activities as defined by the Consent Decree (CD). The primary assessment conducted for each of the City of Baltimore's sewersheds is important for characterizing the condition of the system as it provides important insight into the historical nature of the collection system. The testing and inspection of the wastewater collection system, in what is termed Sewer System Evaluation Survey (SSES), is a significant part of the overall evaluation of the sewershed. These SSES activities include conducting flow monitoring and rainfall data collection programs, completing the inspection of manholes and other sewer structures located within the collection system, completing CCTV inspections of sewers 8-inches in diameter and larger, conducting smoke and dyed-water testing, the preparation, calibration and validation of a hydraulic model, and the identification of critical sewer system components within the collection system and establishing criticality ratings for these components. All data was compiled to formulate a long term rehabilitation and corrective action plan that includes an implementation schedule and estimates of probable costs.

The structure of the SSES program has been established by the City. The City provided guidance and general direction for RJN and all Sewershed Consultants to assure that all tasks completed in support of this study are prepared in a standardized format to facilitate the collection and review of the data for compliance with the requirements of the CD. This information will be used in the preparation of a comprehensive corrective action plan for the City.

The Dundalk Sewershed, one of the eight (8) sewersheds located within the City is a approximately 17.2 square miles, with about 3.9 square miles within the City boundary and the remaining portions located in Baltimore County. As part of this SSES program, approximately 134,000 linear feet of sanitary sewers and 545 manholes have been inspected and being submitted to the City.

The sewers inspected per the CD ranged in size from small 8-inch diameter collector sewers to large 66-inch diameter interceptor sewers. The entire area within the City boundary drains to the Dundalk Pump Station, which discharges to the Outfall Sewershed. All sewage collected in the Dundalk Sewershed is eventually conveyed to and treated at the City's Back River Wastewater Treatment Plant (BRWWTP).

4.2 Manhole Inspections

Manholes are the principal means to access a collection system. As such, effective manhole inspection is important in characterizing the overall condition and connectivity of the collection system. The manhole inspections completed for this project typically served multiple roles, which included characterizing the condition of the structure, identifying system connectivity, assisting in defining the general condition of the sewer segments connected to the structure, providing defect observation data required for the condition assessment and development of subsequent repair recommendations for the structure, and identifying additional potential sources of Inflow and Infiltration (I/I) into the collection system. The inspections also provided updated system attribute data such as pipe diameters, structure type and depths, network connectivity, and sewer system configuration. Collection of this data during the detailed inspections also allowed the City's GIS to be updated accurately and efficiently. These updates included removing structures that were originally identified as sewer structures in the GIS system but were actually not, and accurately updating the GIS with newly identified sewers and sewer structures that were not originally shown in the GIS.

Manholes were inspected as required by the CD in accordance with general guidelines outlined in the Environmental Protection Agency's (EPA) SSES Handbook, the American Society of Civil Engineers (ASCE) Manhole Inspection and Rehabilitation Manual 92, and the newly defined requirements of the National Association of Sewer Service Companies (NASSCO) Manhole Assessment and Certification Program (MACP). All inspections were completed under the guidance of MACP certified inspectors. Manholes that could not be located or opened for inspection were documented for additional action. These structures required additional tools to help locate or open them. All structures will be inspected and incorporated into the City's overall rehabilitation plan.

In certain circumstances, physical manned-entry internal inspections were required. When these were conducted, all entries were carried out in accordance with OSHA's 29 CFR 1910.146 Confined Space Entry Requirements.

To standardize the collection of the manhole inspection data, RJN utilized a computer program selected by the City called Manhole Inspection Application Software (MIAS). MIAS allowed field crews to collect detailed inspection information about the physical characteristics of a manhole or structure, identify any sewer connections to the structure and record details about the environment surrounding the manhole that was needed to accurately characterize the condition of the manhole or structure. In addition to the characteristics of the structure, such as the structure's size, shape and construction material, the MIAS application allowed defects and potential sources of I/I to be recorded. MIAS was designed to provide internal methods that link the inspection photographs of the manhole or defect observations to the manhole database record, making them available for easy review and preparation of formal reports to the City or for review at a later date. MIAS also allows access to the GIS and aerial maps, which provided the inspector with additional system or location information in the field to allow them to accurately complete the inspection and update the detailed inspection database.

The following is a brief description of the process involved in the collection of manhole inspection data for the Dundalk Sewershed. The following descriptions are not intended to cover all aspects of the work performed, rather to provide a general understanding of the data collection and review process.

- A manhole inspection crew consisting of 2 inspectors uses a 1" = 100' scale GIS map to identify manholes to be inspected. This map contains information such as street names, manhole location and ID, flow direction and connectivity of the system with all other upstream and downstream manholes.

- The crew selects a manhole from the database list of manholes and goes to the location where the manhole is shown on the GIS map and performs a visual search in an effort to locate the manhole or structure for inspection. If found, the manhole is located utilizing GPS or other typical survey techniques such as triangulation measurements, and then the manhole is inspected. If the manhole is not found, the position is estimated based on the surrounding objects shown on the map and methods such as probing the soil are used to try to locate the manhole for inspection.

- If a manhole structure is not found after field investigation or cannot be opened, it is noted as "Cannot Locate (CNL)" or "Cannot Open (CNO)" in the MIAS database and forwarded to City maintenance for locating and opening. Once the manhole is made accessible, the inspection team is notified and they revisit the site and complete the inspection.

- Once a manhole is located and opened, the MIAS survey is completed. The format of the MIAS inspection form prompts the inspector to begin their inspection by recording features such as the structure's location, then features and defects are recorded starting at the top of the manhole structure and working down to the invert. These entries include frame/cover type, condition, and materials of construction for the chimney, corbel, barrel, bench and channel and their current condition and evidence of I/I.

- Photographs are obtained and entered into the system for location views and top down views of the manhole; photographs are also collected for the pipe connections and any significant defects when possible.

- Pipe sizes are recorded and located according to clock position with the outgoing pipe always being the 12 o'clock position. Pipe diameter and rim to invert depths are also collected and recorded in MIAS along with the condition of the pipe seals.

- All manholes are then assigned a 1 to 5 condition rating, with 1 being in excellent condition and 5 being in very poor condition and requiring immediate attention.

For prioritizing the maintenance and repair of the manholes, a condition rating scale was used to weight the various types of structural defects and I/I conditions that occurred in different components of the manhole structure. This rating system also allowed for the characterization of operation and maintenance (O&M) type issues such as identification of fats, oils and grease (FOG), debris accumulations, and surcharging of the manhole. During the initial phase of this project, NASSCO introduced a standard for manhole condition assessment. This standard was the Manhole Assessment and Certification Program (MACP), which was subsequently adopted by the City to aid in the consistency of data collected and to provide for a reliable evaluation of each manhole component. The use of this standard provides a baseline condition assessment of the structure, which aids in providing a consistent review of conditions during future inspections. The 1 to 5 condition rating standard used for the manhole inspections is largely based on the ASCE Manual of Practice No. 92, which utilizes a 5-point severity rating system. The following represents the rating scale:

1: Excellent Condition – Only minor defects
2: Good Condition – Defects have not started to deteriorate
3: Fair Condition – Moderate defects that will continue to deteriorate
4: Poor Condition – Severe defects likely to become a grade 5
5: Immediate Attention Required – Defects requiring immediate attention

Table 4.2.1 provides an overview of the condition of the 545 manholes inspected as part of the Dundalk Sewershed manhole inspection program and classifies the manholes by overall structure rating. **Table 4.2.2** provides an overview of the general defect locations within the manhole and **Table 4.2.3** summarizes the total number of defects observed, classifying the conditions by defect type. **Attachment 4.2.1** contains all manhole inspection reports completed for this project.

Table 4.2.1		
Dundalk Sewershed Study and Plan: Sewer System Evaluation Study		
Manhole Condition Summary		
Overall Rating	Count	Percent %
1: Excellent Condition	2	0.4
2: Good Condition	180	33.0
3: Fair Condition	348	63.9
4: Poor Condition	12	2.2
5: Immediate Attention Required	3	0.6
Total Manholes Inspected:	545	100%

Table 4.2.2		
Dundalk Sewershed Plan: Sewer System Evaluation Study		
General Manhole Defect Summary		
Count	Percent	Description
75	13.8%	Manholes that Do Not Leak
470	86.2%	Manholes that Leak
120	22.0%	Frame Leaks
434	79.6%	Chimney Leaks
155	28.4%	Corbel Leaks
162	29.7%	Barrel Leaks
317	58.2%	Bench Leaks
24	4.4%	Channel Leaks

Table 4.2.3	
Dundalk Sewershed Study and Plan: Sewer System Evaluation Study	
Manhole Inspection Defects Summary	
Component	Quantity of Defects
MH Cover Defects	24
MH Frame Defects	226
MH Chimney Defects	1,272
MH Corbel Defects	502
MH Barrel Defects	531
MH Bench Defects	40
MH Channel Defects	30
MH Pipe Defects	704
Pipe Seal Defects	136
MH Steps	97
Total Defects:	3,562

As of May 01, 2010, there were a total of 55 manholes that could not be inspected in Dundalk Sewershed. Two (2) manholes located on Holabird Avenue in basin DU06 could not be inspected due to traffic. Four (4) manholes, located at the old General Motors manufacturing plant in basin DU01, could not be inspected due to construction of Chesapeake Commerce Center. Four (4) manholes, including two manholes on Ralls Avenue in basin DU05, could not be inspected due to heavy debris and high water level. In addition, four (4) other manholes can not be opened with standard tools as they were either bolted or have concrete lids. The remaining 41 manholes were confirmed buried during CCTV inspection and therefore could not be inspected.

To proceed and get all these manholes inspected, it is recommended that the City secure contractors with specialized equipment capable of locating manholes and performing heavy cleaning.

4.3 Closed Circuit Television (CCTV) Inspections

CCTV inspection of sewers is the process of remotely internally inspecting and documenting the condition of conveyance pipes. It also provides valuable insight into the cleaning and maintenance requirements of each sewer segment and provides information that is needed to assign appropriate rehabilitation technologies to deteriorated or damaged pipe segments.

To provide the highest visibility of defects, all sewers inspected were cleaned prior to inspection to accurately define the conditions. Sewers were cleaned utilizing hydraulically propelled high-velocity jet or other mechanically powered equipment. The intent of the cleaning operations was twofold; first, to adequately clean the sewer so the inspection could identify defects that otherwise would not be visible and second, to remove all foreign materials from the sewer to restore the sewer to a minimum of 95% of its original carrying capacity. Since the success of the other phases of work depended on the success of this phase of the operation, it was emphasized. When significant restrictions such as roots or other heavy debris restrictions were encountered, heavy cleaning was utilized to restore the capacity of the sewers and allow for internal inspection. Heavy cleaning involved root cutting or additional passes of the hydro-cleaning equipment. All debris was removed from the sewers. When significant blockages were identified, they were reported to the City and the City promptly coordinated with the wastewater maintenance division or their on-call contractor to resolve the deficiencies.

After cleaning, the sewer segments were inspected by means of closed-circuit television (CCTV) inspection. These inspections were used to identify the following:

- Current pipe condition including existing or potential structural deficiencies or problems, and accurately identifying the pipe's connectivity and location.
- Confirmation, extent, and current condition of previous rehabilitation projects and/or repairs.
- Identifying improper or potentially illicit connections.
- Identifying potential sources and extent of segment I/I.
- Assist in selecting appropriate methods of repair, rehabilitation and/or replacement.

Paragraph 9 of the CD requires that gravity sewers 8 inches and larger in diameter be inspected using CCTV inspection in accordance with NASSCO guidelines. The CCTV inspection of the sewers provided the necessary condition assessment for the SSES evaluation of the Dundalk Sewershed. The inspections identified defects and other problems relating to the sanitary sewer collection and conveyance system that allows the project team to compile a comprehensive corrective action plan and prioritize an implementation schedule.

All CCTV inspections were completed and data collected according to NASSCO's Pipeline Assessment and Certification Program (PACP) guidelines and standards. The City required the use of PACP certified software to collect and record all CCTV information. All CCTV operators, equipment and the review team were certified in the use of the PACP coding system.

All CCTV inspections were conducted using a color pan-and-tilt, radial viewing inspection camera that provides adequate illumination to clearly observe defects and other features within the pipe. All sewers were cleaned before being televised in order to capture the most accurate and complete depiction of defects and features. All surveys were initiated from the upstream manhole proceeding downstream with the flow to minimize splashing of the camera. When defects or other obstructions prevented the completion of the inspection in this direction, a reverse inspection was initiated from the downstream manhole to complete the inspection of the sewer segment. The CCTV camera lens was required to be positioned in the center of the pipe being inspected and movement of the camera through the sewer pipe did not exceed a speed of 30-feet per minute. Wastewater flows in the sewer during the inspection were controlled and did not exceed 20 percent of the pipe capacity for pipes 8”- 10”; 25 percent for pipes 12”- 24”, and 30 percent for pipes 24” and larger per the PACP guidelines. During the internal inspection, the CCTV camera was temporarily stopped at all significant defects and side sewer or service connections to accurately code and provide a clear image of the defect or point of connection. For some larger sewers in Dundalk, CCTV inspection has not yet been completed due to depth and high flow restrictions on camera equipment.

As a means to prioritize the maintenance and repair of pipe sections and other associated sewer appurtenances, a condition rating scale was used to rate the various types and degrees of structural defects and I/I conditions occurring in different segments of the sanitary sewer system. The PACP rating scale was utilized as a standard and consistent format for the way pipes were evaluated and conditions recorded. These standards allow pipe conditions to be reported in a standard recognized manner and allow the City to compare the segment’s condition from one time frame to another and accurately track the condition of the pipe and any progression of defects.

The PACP coding system requires the assignment of a specific code for each structural and O&M type defect identified within a pipe segment. The software automatically assigns a PACP rating code to each defect when entered. The code is a four digit combination of numbers and letters. The first digit is the highest severity grade, the second digit is the number of occurrences of the highest severity, the third digit is the second highest severity grade, and the last digit is the number of occurrences of the second highest severity. If the number of occurrences is greater than 9 then a letter is assigned, such as; A for 10-14 defects, B for 15-19 defects, etc. The grades are assigned based on the potential for further deterioration or possible failure of the pipe. The PACP grading system obtained from NASSCO’s “Pipeline Assessment and Certification Program” reference manual is as follows:

Grade	Description	Time to Failure
5	Immediate Attention Required	Pipe has failed or will fail within 5 years
4	Poor	Pipe will probably fail within 5 to 10 years
3	Fair	Pipe may fail in 10 to 20 years
2	Good	Pipe unlikely to fail for at least 20 years
1	Excellent	Failure unlikely in the foreseeable future

Using this system, each pre-defined defect or observation code is directly associated with a severity rating based on the type and extent of the defect. These ratings aid in determining the need for maintenance, repair, rehabilitation or replacement of the pipe segment. These ratings, in conjunction with the criticality rating of the system component were used to prioritize system repairs. **Table 4.3.1** summarizes the defects recorded during the CCTV inspections by type of defect. **Attachment 4.3.1** is an Access database that contains all CCTV inspection information completed as part of the CCTV inspection program in the Dundalk Sewershed. **Tables 4.3.2 and 4.3.3** summarizes the structural condition ratings and the operation and maintenance condition rating, respectively. The total length of pipe inspected and rated is approximately 133,637 LF.

Table 4.3.1

Dundalk Sewershed Plan: Sewer System Evaluation Study

CCTV Defect Observation Summary

CCTV Inspection Defects		Pipe Size (inches)					Total
Family	Group Type	8"-12"	14"-18"	20"-33"	36"-56"	>60"	
Structural	Break in Pipe	191	9	2	4	1	207
Structural	Collapse	4	0	0	0	0	4
Structural	Cracks	825	160	27	8	2	1,022
Structural	Fracture	511	28	1	1	0	541
Structural	Deformation	24	0	0	0	0	24
Structural	Defective Joints	570	11	4	1	0	586
Structural	Defective Lining	0	0	0	0	0	0
O&M	Defective Taps	257	1	3	1	0	262
O&M	Roots	871	8	11	0	1	891
O&M	Grease	1,658	293	191	527	0	2,669
O&M	Encrustation & Scale	1,994	62	472	85	34	2,647
O&M	Settled Deposits	363	197	121	168	0	849
O&M	Infiltration	192	10	111	15	16	344
O&M	Obstruction	212	22	15	3	0	252
O&M	Line Deviations	74	1	14	7	0	96
O&M	Water Level +20%	539	19	18	3	0	579
Miscellaneous	Survey Abandoned	105	6	4	3	2	120
Miscellaneous	Camera Underwater	23	0	0	0	0	23
	Totals	**8,413**	**827**	**994**	**826**	**56**	**11,116**
	Percentages	**75.7%**	**7.4%**	**8.9%**	**7.4%**	**0.5%**	

Approximately 7,500 LF of sewer within the Dundalk Sewershed could not be televised due to depth/size of sewer and high flows, while another 7,900 LF could not be inspected due to blockages or other conditions that prevented the camera from completing the full segment of pipe (water level, collapse, debris). One such segment is the 27-inch to 36-inch diameter pipe section on Ralls Avenue in the DU05 basin, approximately 5,000 LF. In order to CCTV this section of pipe, it is recommended that the City secure a contractor capable of performing heavy cleaning on large, deep sanitary sewers. This requires special equipment capable of reaching depths over 30-feet and removal of heavy debris while keeping the line in service.

Approximately 2,500 LF of the 66-inch diameter gravity pipe that discharges to the Outfall Sewershed could not be televised due to restricted access and unable to locate manholes. It is recommended that the City utilize a contractor with specialized equipment capable of televising large diameter, deep sewers as well as the capability to locate manholes.

Table 4.3.2		
Dundalk Sewershed Study and Plan: Sewer System Evaluation Study		
Sewer Structural Condition Rating Summary		
Rating	Pipe Segment LF	Percent %
5 - Defects that require immediate attention	1,799	1.3%
4 (Poor) – Severe defects that will become grade 5 in the near future	541	0.4%
3 (Fair) - Moderate defects that will continue to deteriorate	1,675	1.3%
2 (Good) - Minor defects that have not started to deteriorate	8,241	6.2%
1 (Excellent) – No defects or minor defects present	121,380	90.8%
Total:	133,637	100%

Table 4.3.3		
Dundalk Sewershed Study and Plan: Sewer System Evaluation Study		
Sewer Operation and Maintenance Condition Rating Summary		
Rating	Pipe Segment LF	Percent %
5 - Defects that require immediate attention	3,075	2.3%
4 (Poor) – Severe defects that will become grade 5 in the near future	3,296	2.5%
3 (Fair) - Moderate defects that will continue to deteriorate	9,006	6.7%
2 (Good) - Minor defects that have not started to deteriorate	17,060	12.8%
1 (Excellent) – No defects or minor defects present	101,200	75.7%
Total:	133,637	100%

4.4 Smoke Testing

Smoke testing is a means to quickly and effectively identify potential locations of stormwater/groundwater entry into the sanitary sewer collection system. Direct connections including downspouts, area drains, driveway drains, stairwell drains, patio drains, and storm sewer inlets or ditches can be confirmed with smoke testing. Indirect connections from storm sewers or drainage ditches, which allow I/I to pass through soil and into deteriorated or damaged conveyance piping, can also be identified with smoke testing.

The smoke testing efforts for this project were conducted between July and September 2008, during periods when the groundwater table was low and sufficient time had elapsed from any prior rain events. Smoke testing was not allowed to be completed until 24-hours had passed from a wet-weather event to make sure the soils were sufficiently dry to allow detection of smoke. Prior to initiating the smoke testing, per BaSES, an extensive list of property owners, hospitals, nursing homes, schools, daycares, local civic and community leaders, community associations, council members, and police and fire officials were notified. This process included monthly testing notifications and the distribution of detailed smoke testing door hanger notifications, typically extending two blocks outside the test areas three days prior to conducting the tests. Daily notifications of pending smoke testing were sent via email and fax to a list of stakeholders in the area per the smoke testing protocol. This list was updated and protocol was adjusted as required by the project. When smoke testing was initiated and subsequently stopped because of

BALTIMORE CITY DPW DEPARTMENT OF PUBLIC WORKS DAVID E. SCOTT, P.E. DIRECTOR rain, re-initiation of the testing did not occur until conditions were again suitable and the notification process was completed again.

A single blower setup technique was used with theatrical smoke being introduced at the smoke blower and pushed through isolated sections of the pipe. The maximum allowable set-up length was no more than two total manhole segments. Field crews were responsible for determining that adequate smoke coverage was obtained by observing smoke concentrations and observing smoke travel using house plumbing vents along the setup. Smoke was continually introduced into the test setup until adequate smoke coverage was obtained in the test area. In the event that smoke did not travel the entire reach, the setup was reversed by setting the blower on the opposing manhole of the initial setup and re-introducing the smoke. Such situations were often caused by pipe sags that contained flow, grease, debris, collapsed pipes, or other obstructions that would prevent smoke from traveling through the pipe.

Both the upstream and downstream manholes were isolated during the smoke testing to concentrate the smoke within the test section. These restrictions were accomplished using sandbags. Suspect inflow sources such as driveway drains, stairwell drains, window well drains, patio and area drains, and downspouts piped underground, or foundation drains were noted. Significant potential sources of “clear water” connections (such as storm drain or catch basin connections) were noted and were recommended for follow-up dyed-water testing to determine if actual cross connections existed. Care was taken to inspect the property around all buildings for sources of smoke. In situations where heavy smoke exited a source and it could be determined and documented through observation that the source was directly connected to the sanitary sewer, further investigation was not necessary. Generally, in all other situations where it could not be accurately determined if the source was directly connected to the sanitary sewer, further dyed-water testing was scheduled.

Table 4.4.1 summarizes the defects identified during the smoke testing inspections, identified by type of defect or source, defect location, sector (public or private) and the severity of the defect. **Attachment 4.4.1** contains all smoke testing inspection data completed for the Dundalk Sewershed.

Table 4.4.1			
Dundalk Sewershed Study and Plan: Sewer System Evaluation Study			
Smoke Testing Defect Summary			
Code	Sector	Total Defects	Percent (%)
1	Public	25	7
2	Private	325	93
	Total:	**350**	**100**
Code	Source Type	Total Observations	Percent
1	Curb and Gutter	0	0
2	Sidewalk	1	0
3	Water Meter	0	0
4	Storm CB Connection	0	0
5	Manhole Defect	4	1
6	Private Cleanout/Riser	127	36
7	Private Cleanout Cap	78	22
8	Sewer Main	15	4
9	Private Building Lateral	107	31
10	Storm Connection	5	1
11	Driveway Drain	0	0
12	Suspect Area Drain	1	0
13	Patio Drain	0	0
14	Sump Pump	0	0
15	Connected Area Drain	0	0
16	Downspouts	5	1
17	Building Front	0	0
18	Building Side	0	0
19	Building Rear	0	0
20	No Vent Smoke	0	0
21	Building Interior	7	2
	Total:	**350**	**100**

As shown in Table 4.4.1, several defects were identified during the smoke testing and defect items coded as 6 – Private Cleanout/Riser, 7 – Private Cleanout Cap, 9 – Private Building Lateral, 10 – Storm Connection, 12 – Suspect Area Drain, 16 – Downspouts, and 21 – Building Interior were scheduled for additional investigation utilizing dyed-water testing.

4.5 Dye Testing

Dyed-water testing or flooding of areas such as storm drain catch basins was also conducted as part of the field study of the collection system. The dyed-water flood tests helped to detect pipe segments that were either direct or indirect connections between the storm drain and sanitary sewer system. Direct connections were typically identified during the smoke testing operations; however, any suspected locations were further investigated using dyed-water flooding or tracing. To complete this testing, the suspect storm drain, catch basin or other area was flooded with dyed-water and the adjacent connecting sanitary sewer manholes were observed for the presence of dye in the flow. In more detailed situations, the storm drain was plugged and filled with dyed-water and allowed to sit for an extended period of time to allow the dyed-water to permeate the surrounding soils and identify leakage points in the collection system piping.

Typically a waiting period of at least thirty minutes following the initiation of the dyed-water was used before the test could be considered negative.

Table 4.5.1 summarizes the tests by location and type, and identifies all defects observed during the dyed-water testing inspections. **Attachment 4.4.2** contains all dyed-water tests completed.

Table 4.5.1			
Dundalk Sewershed Study and Plan: Sewer System Evaluation Study			
Dyed-Water Testing Defect Summary			
Code	Sector	Total Defects	Percent (%)
1	Public	7	25
2	Private	21	75
	Total:	**28**	**100**
Code	Source Type	Total Observations	Percent
1	Storm Sewer	0	0
2	Storm Ditch	0	0
3	Depressed Grass Area	19	67
4	Depressed Pavement Area	1	4
5	Sanitary Sewer Manhole	6	21
6	Catch Basin	0	0
7	Septic Field	0	0
8	Roof Drain	1	4
9	Downspout	1	4
10	Driveway Area Drain	0	0
11	Stairwell Drain	0	0
	Total:	**28**	**100**

As shown in Table 4.5.1, the various observations of positive dye testings including the depressed grass and pavement area observations showed connections between the storm drains and the sanitary sewer systems, as large amount of dyed water was found in adjacent manholes. However, all dyed water testings provided no evidence of illegal or direct cross connection, but rather evidence of trench migration or indirect connection. All of these observations have been reported to the City.

The five (5) storm connections identified in Table 4.4.1 during smoke testing verified connections between catch basins and sewer pipes, as smoke was observed at storm grates for each of the manholes identified. Dyed water testing performed at storm drain catch basins around these manholes provided no evidence of direct cross connections, but rather evidence of possible trench migration or indirect connections.

4.6 Emergency Repairs/Rehabilitation

Paragraph 9 C (iii) of the CD states "Identify all rehabilitation or other corrective actions taken by Baltimore (including but not limited to grouting, point repairs, liner replacement) to address the deficiencies identified during evaluation of the sewershed." In support of this effort, the project team reported all significant system defects observed during field inspections or when reviewing the collected data as part of the sewer system evaluation phase. Upon discovery of these deficiencies, the information was compiled and detailed maps, CCTV video and photographs were provided to the City. In some cases the City's non-emergency assistance hotline (311) was also contacted. Figure 4.6.1 indicates the locations of reported significant deficiencies observed in the Dundalk Sewershed.

Figure 4.6.1: Emergency Repair/Rehabilitation Locations in the Dundalk Sewershed

4.7 Pumping Station Evaluation

The Dundalk Sewershed includes one major pump station. The Dundalk pump station is located on Broening Highway near the intersection of Broening Highway and Keith Avenue and was constructed in the 1940's. A rehabilitation project on the pump station was completed in August 2005. The rehabilitation included replacing the existing four pumps with new pumps with variable frequency drives and controls, replacing existing valve actuators with new electrical actuators, replacing the existing three generators with a new 1,000kW generator, and installing a new control system. The capacity of the station is designed for 33 MGD. The Dundalk Pump Station was evaluated for capacity issues using the hydraulic model; see Section 5.0 of this report for details.

4.8 Force Main Inspection

The Dundalk Sewershed includes a 36-inch diameter force main that begins at the Dundalk pump station. The force main is made of cast iron and measures approximately 4,000 linear feet. The force main inspection was performed using a Sahara® Leak Location System, a non-destructive, in-line technology that did not require the interruption of sewer services. With this technology, a sensor head was successfully inserted into the force main through a 30" gate valve chamber just outside of the Dundalk Pump Station on March 17, 2009. The inspection stopped after reaching 1,932 feet due to high pull back pressures on the sensor and cable.

According to the plan drawings of the force main the sensor should have cumulatively completed 187 degrees of bends at this point of the inspection. This number theoretically should not be able to produce a high pull back pressure; it is therefore suspected that the force main has a higher number of as-built bends than is depicted on the plan and profile drawings. Later information received through RJN Group Inc. from the City of Baltimore revealed that the force main undertakes a diversion with four (4) ninety degree bends installed onto the line to create the diversion. The diversion, a new section of Ductile Iron (DI) force main, was put in place in year 1997, is parallel to the original cast iron section, and travels underneath the building at 6200 Beckley Street.

The diversion is approximately 640 feet, of which a distance of nearly 500 feet was covered in the inspection of March 17, 2009. It was agreed with RJN Group Inc. to resume the force main inspection starting at the end of the diversion. RJN Group Inc. coordinated with the Pressure Pipe Inspection Company, the City of Baltimore, and the tapping contractor on the placement of a tap on a force main chamber at the end of the diversion for the purpose of completing the force main inspection. The inspection resumed on November 30, 2009 and covered a total of approximately 1,920 feet of the force main.

The inspections in March and November of 2009 covered a total of 3,852 feet of the force main and identified no leaks or air pockets in the inspected sections. As part of the inspection process, a transient pressure monitoring unit was also installed and recorded data over eight days. The monitoring unit detected 45 pressure spikes or "water hammers", over the monitoring period ranging from 0.3 psi to 55.4 psi. These transients may affect the structural condition of the force main. Attachment 4.8.1 provides the complete report of the Dundalk 36-inch Cast Iron Force Main Inspection.

4.9 Quality Assurance/ Quality Control Procedures

The following sections provide a brief description of the Quality Assurance / Quality Control (QA/QC) review process that all inspections underwent before they were considered complete and delivered to the City. The BaSES manual provided basic guidelines that RJN followed in the QA/QC process as well as documenting an approved Data Management Plan.

4.9.1 Manhole Inspections QA/QC Procedures

- MIAS contains several internal field checks, which prompt the inspector to verify information as it is entered. (e.g.: if an inspector enters the invert elevation of an outgoing pipe at a higher elevation than the incoming pipe's invert elevation, the check prompts the inspector to verify the information). Several of these internal checks will not allow the inspector to move on to the next entry item in the inspection until the prior inspection item has been successfully completed.

- Basic information regarding location and system connectivity was compared with existing information or contract documents. Connecting manhole nodes entered in MIAS were compared to what was shown on the mapping and corrections were made as necessary. If corrections were necessary to connecting nodes, a map correction form was completed which showed the updated connections as they were found in the field.

- All information was reviewed, which included reviewing for errors, assuring photograph quality and reviewing all comments entered by the inspector for clarity and content.

- If there was information missing, the MIAS record was failed and returned to a field crew to revisit the site and collect the required information or the reviewer would utilize existing record documents to obtain the required information.

- When the follow-up information was collected by the field crew or addressed by the reviewer utilizing record data, the new information was again reviewed and if acceptable, added to the record. The record was then tagged as QA/QC complete and flagged for submittal to the City.

4.9.2 CCTV Inspections QA/QC Procedures:

- All CCTV inspections were reviewed in house for conformance with PACP coding guidelines (video quality, flow levels, header information, all defects coded, and coded properly).
-
- Review all CCTV footage and inspection logs for significant defects such as collapsed pipe, blockages, etc. and forwarded these defects to the City for action.
-
- Review CCTV footage and inspection logs for significant O&M items such as excessive grease, roots, etc. and forwarded these defects to the City for action.
-
- If issues were found with video quality or PACP coding of defects for the segment inspected, the inspection record was returned to the CCTV contractor with review comments for recoding or re-surveying.

4.9.3 Smoke Testing QA/QC Procedures:

- All completed field reports were reviewed for conformance to the project guidelines and accuracy assuring that all maps, defect information and photographs are complete, clear, accurate and compatible.
-
- Review all smoke testing entries entered into the Access database to assure all observations and photographs are in accordance with the database scheme and specifications outlined for the project.
-
- If any field data collected was questionable, incomplete or illegible, the data was returned to the assigned field crew with review comments for correction and resubmission.
-

- Review all data submitted to identify significant defects such as cross connections. Any significant findings were reviewed and if required, assigned for further evaluation utilizing dyed-water testing.

- Any confirmed cross-connection, major defect, or illegal connection is submitted to the City for follow-up action, and is documented in the Sewershed Study and Plan Report.

4.9.4 Dyed-Water Testing QA/QC Procedures:

- All completed field data was reviewed for conformance with the project guidelines and accuracy requirements assuring that all maps, defect information and photographs are complete, clear, accurate and compatible.
-
- All dyed-water testing information was entered into the Access database to assure all observations and photographs are in accordance with the database scheme and specifications outlined for the project.
-
- If any field data collected was questionable, incomplete or illegible, the data was returned to the assigned field crew with review comments for correction and resubmission.
-
- Any confirmed cross-connection, major defect, or illegal connection is submitted to the City for follow-up action, and is documented in the Sewershed Study and Plan Report.

In addition, copies of internal manuals developed by RJN for Manhole Inspections, CCTV Inspections, Smoke Testing, and Dyed Water Testing are included as **Attachments 4.9.1 through Attachment 4.9.4** of this report. These manuals are used internally to insure the consistency and accuracy of the data being provided to the City.

5.0 Hydraulic Modeling

As required in Paragraph 12.A of the Consent Decree (CD), a model was developed for the Dundalk Sewershed within the City to assess the capacity of the collection system and to identify the measures necessary to address capacity limitations. The model created is capable of evaluating the impact of inflow and infiltration (I/I) rehabilitation projects, proposed system modifications, upgrades, and expansions to the transmission capacity and performance of the collection system.

Per Paragraph 12.B of the CD, the model prepared is capable of predicting:

a. The volume of wastewater flow in the force mains and major gravity lines
b. Hydraulic pressure or hydraulic grade line of wastewater at any point in the force mains and the major gravity lines
c. Flow capacity of the Dundalk Pump Station
d. Flow capacity of the Dundalk Pump Station with its back-up pump out of service
e. Peak flows for the Dundalk Pump Station during storm events of a magnitude of up to 20 years
f. Likelihood and location of sanitary sewer overflows (SSOs) under high flow conditions, including pump station service areas where the pump station's back-up pump is out-of-service, and considering available wet well capacity, off-line storage capacity, and normal in-line storage capacity.

The model is also:

a. Configured based on representative, accurate, and verified system attribute data (i.e., pipe sizes and invert elevations, manhole rim elevations, etc.)
b. Calibrated using spatially and temporally representative rainfall data and flow data obtained during the rainfall and flow monitoring
c. Verified using spatially and temporally representative rainfall data and flow data; that data shall be independent of the data used to calibrate the model.

The model was calibrated per Paragraph 12.E.ii and the Model Development and Calibration Report is included in Attachment 5.2.1.

5.1 Model Network

The City of Baltimore selected InfoWorks CS from Wallingford Software, Ltd. to model and evaluate the collection systems of all the sewersheds.

The Dundalk Sewershed network that RJN modeled includes all force mains, major gravity lines, a pump station and its related appurtenances. The model also includes an outfall with a water level boundary condition, manholes and junctions along the sewer lines.

The City's wastewater geographic information system (GIS) was used as the primary source of information for creating and populating the pipes and nodes network of the InfoWorks hydraulic model. Data from manhole inspections and CCTV information from field surveys, along with City engineering documents (e.g. as-built record drawings), were used to supplement, verify or correct the City's wastewater GIS.

To populate the rim elevations of the modeled manholes and the inverts of the modeled sewers, survey crews were dispatched to obtain survey-grade elevations and invert depths of the hydraulic model manholes. Where field information was not available, elevations and inverts were established through a review of as-built drawings. There were a small percentage of model-related rim elevations and invert depths that were not available from GPS or through document research. These elevations were estimated using available information and sound engineering judgment.

Before calibration and further modeling efforts were performed, the hydraulic model was validated. A standard validation was conducted to check for missing values (e.g., missing rim elevations) and errors (e.g., isolated manholes) in the network. Further engineering validation was performed to check if any network data was inconsistent with engineering expectations (e.g. negative pipe gradients, flat or extremely steep pipe gradients). Discrepancies were corrected by comparing the model to field and record drawing information.

The InfoWorks CS model for the Dundalk sewershed incorporates the hydrologic characteristics of the sewershed. The model utilizes the SWMM (Storm Water Management Model) surface runoff routine within InfoWorks, which requires that wet weather flow input to the sanitary sewer system be represented differently. The SWMM surface runoff routine is used as a surrogate rainfall-dependent infiltration and inflow (RDII) simulator, meaning that although the parameters used in the runoff routines are adjusted to match the observed inflow, those parameters do not have physical significance. Hence, for wet weather flow simulation in separate sanitary sewers, the surface runoff routine of SWMM is being applied to empirically develop RDII flows in the InfoWorks model. This procedure has the advantage of allowing inflow simulation as a function of any rainfall depth and distribution, within the framework of the model rather than outside of it.

The Dundalk sewershed was divided into 33 sewershed service areas (SSAs). These SSAs were further sub-divided into 91 sub-catchments to better define the sewer network and land use. Sub-catchments were delineated using the following guidelines:

- Sub-catchment areas should be roughly 10-40 acres in size, with an average of approximately 20 acres with the exception of catchments at upstream boundaries, which may be larger.
- Sub-catchment boundaries should generally be drawn at hydraulic control points such as:
    - Flow diversion chambers
    - Pump stations
    - Any constructed overflow point
    - Significant tributary junctions
    - Flow monitor locations
- Large parcels of land such as parks, golf courses and freeways that are not connected to the collection system should be excluded from the sub-catchments for the purposes of collection system modeling
- Sub-catchment delineations should not cross over combined or sanitary pipes: they should always end at a manhole

For each sub-catchment, a load point node was identified for the assignment of dry and wet weather flows into the hydraulic model network. Model load points were assigned to best represent the affects of flows entering the system.

There were several sources of data used in the development of dry-weather flows in the InfoWorks model. These sources include:

- Analyses of the rainfall/flow monitoring data using the Sliicer.com software
- The City's database of water consumption records for each SSA
- Population estimates for each flow monitoring basin obtained through GIS intersection with the U.S. Census Block data
- GIS estimates of tributary collection system to each flow monitor in inch-diameter-miles (idm)

- GIS estimates of the tributary sewershed area to each flow monitor

The flow analysis obtained using the Sliicer.com software provided estimates of the components of the dry-weather flow at each flow monitoring site, namely the average base sanitary flow (BSF) and the groundwater infiltration (GWI) rate.

These values were validated prior to input into the InfoWorks model. Per capita wastewater generation rate was used to validate the BSFs for residential areas. This was performed by dividing the BSF by the population associated with the monitoring basin area. These results were then compared to typical textbook ranges of values for residential areas.

For basins which included industrial and commercial water users, a database provided by the City was reviewed to determine average daily BSFs from these facilities. The database provided water consumption records for the top 100 industrial and commercial water users in Dundalk. A return factor of 0.75 was applied to the water consumption data to account for flows that were not returned to the collection system. A review of NPDES (National Pollutant Discharge Elimination System) permits for wastewater discharge from several of the largest water users in Dundalk verified that the return factor of 0.75 is reasonable.

The Sliicer.com analysis yielded average daily dry weather flow hydrographs for each monitoring basin for both weekdays and weekends. This data was used to develop hourly diurnal peaking factors for weekdays and weekends. This was done by first subtracting the GWI from the hourly values of the dry weather flow hydrographs and then dividing by the average BSF.

In the InfoWorks model, a profile was created for each monitoring basin. The wastewater profile also contains weekday and weekend hourly diurnal peaking factors. In addition, a per capita wastewater generation rate was specified in the wastewater profile. This generation rate, multiplied by the sub-catchment population, yields the average BSF.

The GWI for a given monitoring basin was distributed to the tributary sub-catchments based on relative sewershed area. A GWI profile that contains hourly diurnal peaking factors throughout a day and monthly peaking factors throughout a year was created for each basin. The GWI was represented as a constant inflow throughout a day; therefore, the hourly peaking factors in the profile were set as one (1). The monthly peaking factors in the profile were set as one (1) initially and adjusted based on one year of flow data from May 2006 to May 2007 to represent seasonal variation of groundwater levels.

Analysis of the monitoring data also yielded model input for the simulation of wet-weather events. The wet-weather flow component in sanitary sewers is referred to as rainfall-dependent infiltration and inflow (RDII).

The approach to simulate wet weather flow in areas served by separate storm sewers uses the SWMM RUNOFF routines in InfoWorks CS as a synthetic storm hydrograph generator. In a sanitary system, the RDII is driven not by the impervious surface of a catchment, but rather by a myriad of factors including:

- Age and condition of the system
- Construction practices at the time of installation
- Prevalence of direct (illicit) connections to the sanitary system
- Operation and maintenance of the system
- Antecedent moisture conditions (the saturation of the ground around the sewers)
- Groundwater elevation

To simulate inflow into sanitary sewer systems, suitable input parameters were selected to yield flow that matches inflows determined from flow meter measurements. The following is a description of each of these parameters in SWMM RUNOFF routines.

Simulating RDII using SWMM RUNOFF within InfoWorks requires the specification of catchment characteristics that result in correct RDII. The parameters to be specified are:

- Area: The total area of each sub-catchment (in acres) is calculated in GIS.

- R-Value (Percent Capture): The SWMM RUNOFF routines simulate wet weather from a modeled basin via impervious and pervious runoff. For sanitary sewer systems, the percent impervious is analogous to a percent capture or more appropriate an RDII "R-Value". The R-Value represents the fraction of the rainfall that enters the sanitary system. Sliicer.com provides an estimate of the R-Value.

- Depression storage: Depression storage represents the volume, in inches, that must be filled prior to the occurrence of runoff. For surface runoff it represents the initial loss or "abstraction" caused by such phenomena as surface ponding, surface wetting, interception and evaporation. For the RDII modeling purposes, this parameter represents the depth of rainfall required to initiate a response in the sewer system. In this case, depression storage has been estimated using the intercept of the RDII volume vs. rainfall (Q vs. i plot in Sliicer.com) regression line.

- Width: The sub-catchment width is a key calibration parameter, one of the few that can significantly alter the hydrograph shape (timing of the peak flow rates) without impacting the volume. The width is determined when the simulated time-to-peak and magnitude match the observed peak RDII flow during several storms. This has been done by simulating the storm events using the model and adjusting the catchment width until the correct peak is obtained. Sub-catchment width is directly proportional to peak flow rate.

The RDII volume versus rainfall depth plot for each monitoring site was developed using the Sliicer.com software. In addition, Sliicer.com developed the best-fit linear regression to the data set and the corresponding equation for the regression line, as well as the R-Value. All 29 storms selected by the City had been considered in this analysis. For a list of storms, refer to Table 3.4.1 in Section 3.4 of this report.

To accurately reflect the hydraulics of the sewershed (e.g. backwater condition), boundary conditions had to be setup within the model. Two types of boundary conditions exist for the Dundalk Sewershed: 1) flows from Baltimore County and, 2) wastewater level condition at the outfall where Dundalk discharges into the Outfall Sewershed Interceptor. There are four major sources of flow from Baltimore County and the Capture coefficient or "R" values for these County basins were first estimated through Sliicer.com then fine-tuned through the calibration effort.

To determine the wastewater level condition at the outfall of the Dundalk Sewershed, a simple hydraulic model was built. The flows at manhole S65A__011MH (TSDU03 meter data) immediately upstream of the outfall were utilized. In addition, approximately 34.3 inches of sediments in the Outfall Sewershed Interceptor was incorporated into this model.

5.2 Model Calibration

After the Dundalk Sewershed Model Network had been developed and flows imported, the next step of the development process was calibrating the model. This consisted of changing characteristics of the network and sub-catchments to accurately portray what is happening in the real world.

Model calibration consisted of two steps; first, the dry weather calibration, followed by the wet weather calibration.

The first step, dry weather calibration, was the process of modifying the network to reflect what is actually happening in the sewer system during a normal dry day. The dry weather calibration began with incorporating significant defects and unusual hydraulic conditions identified during the manhole inspection. Sediment depths, blockages, and other flow restrictions were identified and then incorporated into the model. Based on the type of defect identified, Manning's "n" was adjusted to reflect increased roughness. After this, the simulation was run to get a first glimpse of the behavior of the model. Following the simulation, "Observed vs. Predicted" plots were generated for each flow monitoring site to see how the model behaved compared to the flow meter data.

The following criteria were followed for the dry weather calibration:

- The modeled peak flow rate should be within -10 to +20 percent of the observed.
- The modeled volume of flow should be within -10 to +20 percent of the observed.
- The timing of the peaks should be within 1 hour.

Any discrepancies observed between the modeled behavior and flow meter data were corrected by adjusting the diurnal curves, the roughness factors, and sediment depths.

The dry weather calibration was initially run for a two-day period (Friday and Saturday) so that modeled response (i.e., hydrograph shape, peak flow rate, volume, and peaking time) can be checked for weekdays and weekends. Modeled response was compared to average dry weather flows during summer 2006 with the exception of meter basins BDU03 and BDU04. Meters BDU03 and BDU04 were installed in March 2008 and modeled response for these basins was compared to average dry weather flow in a period from March 14 2008 to June 30 2008. To further verify the model, modeled response was compared to dry weather flows in a winter week February 5 through February 12, 2007 when GWI was elevated due to higher groundwater level. All of the meters met the criteria for dry weather calibration.

After the dry weather calibration, the second step was wet weather calibration. This process involved adjusting sub-catchment parameters to make predicted hydrographs behave similar to observed hydrographs under storm events. The sub-catchments, in varying proportions, were composed of three types of runoff surfaces: road, roof, and pervious area (e.g. lawn). These surfaces represent paths that storm water can take to enter the sewer collection system.

Capture coefficients were developed from Sliicer.com and entered into the model's sub-catchments as "Fixed Runoff Coefficients". Then the model was run using InfoWorks default values for basin slope and basin width. After reviewing the preliminary results, different parameters were adjusted to predict the flow meter responses more accurately.

The following are the guidelines followed for the wet weather calibration:

- The modeled peak flow rate should be within -10 percent and +25 percent of the observed peak rate.
- The modeled volume of flow should be within -10 percent and +20 percent of the observed flow volume.
- The modeled depth of flow in surcharged sewers 21 inches in diameter and larger should be within - 4 inches and +18 inches of the observed flow depth. The modeled depth of flow in surcharged sewers smaller than 21 inches should be within -4 inches and +6 inches of the observed flow depth.

- The modeled depth of flow at non-surcharged critical points in the system, i.e., at SSO structures, should be within 4 inches of the observed flow depth.
- The shape and timing of the hydrographs should be similar.

For the wet-weather calibration it was noted that significantly more rain entered the sewers during the winter months compared to the summer months. This is due to the behavior differences of summer and winter storms. Summer storms typically are of shorter duration and higher intensity than winter storms; whereas winter storms are typically longer in duration, but lower in intensity than summer events. In addition, the ground is dryer and the water table is lower in the summer than in winter, resulting in less runoff per rain volume than compared to winter storms. This difference between summer and winter storms made it difficult to calibrate the model to predict storm events during both seasons. If the model is only calibrated to summer events, potential deficiencies in the system may not be fully captured; however, if only calibrated to predict winter storms, required improvements may be grossly over-predicted. Therefore, the average of the summer and winter R was used in the model as a compromise. Using a median R-value introduced a safety margin by allowing a higher than normal R during the more severe storms in the summer. Furthermore, by using this method the calibration guidelines were generally met.

In summary, the hydraulic model of the Dundalk Sewershed was built in accordance with the CD. The network was built from field verified GIS information and the flow inputs were based on the flow meters installed for over one (1) year. Dry weather calibration was completed taking unusual hydraulic conditions into consideration, such as sediment. For the wet weather calibration, the median R value was used to capture the differences between winter and summer storm events. Consequently, when simulating all of the 29 modeled storms as a whole and balancing the differences, the model behaved in a realistic fashion.

For a full description of the model calibration process, see Attachment 5.2.1, Dundalk Model Development and Calibration Report.

5.3 Baseline Analysis and Capacity Assessment

5.3.1 Design Storms

Seven design storms were analyzed for this assessment. These design storms include the 1, 2, 5, 10, 15, and 20-year, 24 hour duration storms under baseline (Year 2007) and future (Year 2025) conditions. The difference in flow between baseline and future conditions takes into account the contribution of population changes, industrial flow changes from redevelopment of land, and pipe deterioration. A three (3) month storm was also assessed for the duration of 1.5 hours, which is the time of concentration for the Dundalk Sewershed (i.e., time for the entire Dundalk Sewershed to contribute flow to the Dundalk Pump Station under a rainfall event). The storm distribution chosen for analysis is the NOAA Atlas 14/NRCS distribution. The storm depths for the seven design storms are as follows:

- 3-Month – 0.81 inches
- 1-Year – 2.67 inches
- 2-Year – 3.23 inches
- 5-Year – 4.15 inches
- 10-Year – 4.97 inches
- 15-Year – 5.41 inches
- 20-Year – 5.82 inches

5.3.2 Definition of Deficiency

According to a City memorandum issued on July 26 2008, the standard for capacity adequacy will be to keep the flow in the system and to allow the system to surcharge. Regardless of the storm, capacity will be considered adequate as long as no SSO occurs. Therefore, as long as there is no SSO in the Dundalk Sewershed, there will be no system deficiency.

5.3.3 Storm Simulations (All Storms)

One of the requirements of the CD is to assess existing and long-term capacity of the collection system and to evaluate the ability of the collection system to transmit peak flows under dry weather and wet weather conditions. For analysis of wet weather conditions, the CD requires a Return Period Analysis (RPA) to be performed on the three (3) month design storm and the remaining six design storms under baseline and Year-2025 (future) conditions. InfoWorks compares any flooding based on each design storm and presents the minimum size storm required to cause an SSO, as well as the estimated flood volume. In addition, InfoWorks identifies hydraulic flow restrictions through the Return Period Analysis. The hydraulic flow restriction is performed by comparing the slope of each pipe to the slope of the hydraulic grade line at peak flow. A surcharged sewer with a pipe slope flatter than the slope of the hydraulic grade line indicates that the sewer has limited capacity to handle the peak flow (i.e., flow restriction). If the pipe slope is steeper than the slope of the hydraulic grade line, then the sewer is in a backwater condition caused by a downstream control.

As required by the BaSES manual, RJN performed a capacity assessment under baseline and future conditions for two scenarios based on the operation of the Dundalk Pump Station:

(1) All pumps are online (3 main pumps and 1 backup pump)
(2) Backup pump is offline (3 main pumps online only)

Baseline Conditions

During dry weather conditions, there were no SSOs or surcharges in the Dundalk sewershed under baseline conditions. The Dundalk Pump Station handled an average inflow of 5.41 MGD and a peak inflow of 6.11 MGD from the Dundalk sewershed. During both pumping scenarios, one (1) pump sufficiently handled dry weather inflow to the pump station with a peak pumping rate of 6.32 MGD. Under the baseline condition, one pump can lift sewerage 85 feet (static head) from the wet well to the discharge end of the 36-inch diameter force main. It is important that the velocity within the force main does remain low enough in order to prevent excessive head on the pumps and protect the system from scour effects. For the capacity analysis of the force mains in the Dundalk sewershed model, a velocity greater than 7 feet per second is considered excessive. The hydraulic model predicted that peak velocities in both pumping scenarios remained below 7 feet per second for the dry weather condition.

During the wet weather condition, there were no SSOs during the three (3) month and 1 year storm events. However, during the 2 year storm event, SSOs started to occur at 3 manholes in basins DU06 and DU07 under both pumping scenarios. In addition, peak velocities in the 36-inch diameter force main started to exceed the velocity threshold of 7 feet per second. As the storm return period increased, SSOs spread throughout the Dundalk sewershed and the number of overflowing manholes increased to 22 with a total flood volume of 0.57 MG during the 20-year storm event under both pumping scenarios. No evidence of an SSO was present in basins DU02 and DU04.

Map 5.3.3A & 5.3.3B depicts the SSO and flow restriction locations for all seven design storm simulations under the two pumping scenarios.

Future Conditions – Year-2025

Although dry weather flows for the Year 2025 increased 9.1% from 2007 due to estimated population changes, industrial flow changes from the redevelopment of land, and sewer deterioration, the hydraulic model still predicted no overflows under both pumping scenarios. One (1) pump alone sufficiently handled peak dry weather inflow to the pump station of 6.67 MGD with a peak pumping rate of 6.94 MGD.

Similar to the baseline condition, SSOs began during the 2 year storm event, at 3 manholes in basins DU06 and DU07 under both pumping scenarios. Also peak velocities in the 36-inch diameter force main exceeded 7 feet per second for the 2-year storm and above. As the storm return period increased, SSOs spread throughout the Dundalk Sewershed and the number of overflowing manholes increased to 23 SSOs with a total flood volume of 0.61 MG during the 20-year storm under both pumping scenarios. The surcharge pattern remained the same between baseline conditions and future conditions.

Map 5.3.3C & 5.3.3D depicts the SSO and flow restriction locations for all seven design storm simulations under the two pumping scenarios.

5.3.4 Identification of Hydraulic Deficiencies (All Storms)

One of the requirements of the CD is to identify and map all components of the wastewater collection system that restrict flow of wastewater through the collection system and that cause or contribute, or are likely to cause or contribute, to overflows from the collection system. Maps and descriptions of the hydraulic restriction in the Dundalk Sewershed are provided in the Baseline Assessment and Capacity Analysis Report in **Attachment 5.3.1.**

Most of the pipe capacity deficiencies in the Dundalk Sewershed are due to RDII. However, this study also identified two locations, where construction defects, in addition to high levels of RDII, are major causes of SSOs.

1. Basin DU06 **-** Basin BDU01 discharges to a section of 15-inch diameter pipe in basin DU06, and this section of pipe reduces in diameter to 12 inches and then connects to a 27-inch diameter pipe along Dundalk Avenue. The 12-inch diameter pipe restricts flow and is a major cause of SSOs upstream in the DU06 Basin. **Section 5.4**, of this report provides detailed recommendations for this location under the 2-year and larger design storms,

2. Basin DU07 - A section of pipe along Boston Street in basin DU07 begins as a 10-inch diameter pipe, increases to a 12-inch diameter pipe, then reduces to 10 inches, and then increases again to a 12-inch diameter pipe. The section of 10-inch diameter pipe in the middle restricts flow and causes SSOs at this site under the 15 and 20-year storms. However, upon completion of the recommended 2, 5, and 10-year improvements discussed below, there were no more SSOs at this location, even under the 15 and 20-year design storms.

The three main pumps and the wet well at the Dundalk Pump Station have sufficient capacity to handle peak dry weather flows. During wet weather storm events (the 5-year storm or above), simulations suggested operation of all 4 pumps at the pump station can handle peak wet weather flows. The wet well has additional remaining capacity even while one pump is offline for maintenance; therefore no pump station upgrade is required. For the 2-year storm and above, the 36-inch diameter force main was not in compliance with the velocity threshold of 7 feet per second; a more frequent force main inspection or an upgrade of the force main is required to ensure its structural integrity and normal functioning.

5.4 Alternative Analysis (2-Year and Larger Storms)

In evaluating improvement options for the Dundalk Sewershed, emphasis was placed on I/I removal, removing the inflow and infiltration from upstream locations of the identified SSO locations. Information from the closed circuit television (CCTV) inspections, flow metering results, and smoke and dye testing were used in selecting the areas that are recommended for I/I removal.

Based on the technical program guideline provided by the City, it is estimated that up to 80% reduction in RDII and dry weather base infiltration (I/I) can be achieved if a comprehensive I/I removal program (cured in place pipe (CIPP) lining of all public and private sewers and manhole rehabilitation/replacement) is implemented.

The I/I removal program RJN is recommending will involve rehabilitating manholes and sewers upstream of the predicted overflow locations such that sources of I/I can be eliminated. As it is proposed to only rehabilitate the public side of the collection system, the Dundalk model was modified to account for 40% reduction in RDII in the locations selected for I/I reduction.

These analyses assumed no I/I reduction from the four Baltimore County basins. The County is in the beginning phases of their CD with the Environmental Protection Agency (EPA), which will not be completed for several years after the Dundalk Sewershed Study is scheduled to be completed. However, any I/I reduction the County may achieve will introduce an additional margin of safety for the recommended improvements.

Other alternatives RJN is recommending to remove SSOs include upsizing pipes to accommodate the flows, adding storage where necessary, and pump station upgrades.

For a complete description of the proposed projects to eliminate all SSOs for the required design storms and a break down of the individual project costs, refer to the Dundalk Alternatives Analysis and Recommendations Report in **Attachment 5.4.1.**

2-Year Storm Improvements

Map 5.4.1 Dundalk Alternative Analysis (2 – Year Storm), at the end of this section, shows the locations and conditions of areas needing improvements for the 2-year storm event. These areas are summarized below.

DU06

In this basin, the model predicts two (2) overflows under the 2-year, 24 hour design storm and the overflows occur on a section of 8-inch diameter pipe along Portal Street. I/I analysis indicates that DU06 has one of the highest RDII and dry weather base infiltration rates. This was also confirmed by CCTV inspection, smoke testing, and dyed water testing, showing defective cleanouts, defective building laterals, and defective pipes and manholes.

Therefore, it is recommended to perform an extensive I/I removal project in the areas upstream of the overflowing manholes including sub-catchments 29-02-06-00A, 29-02-06-00B, and 29-02-06-00C. The I/I removal project will involve performing cured in place pipe (CIPP) lining on pipe sections upstream and rehabilitating all manholes upstream of manhole S71W__001MH, between Chandlery Street and Tributary Street. The estimated cost for this project is $237,000 in 2008 dollars.

The I/I removal project will reduce the 2-year RDII for the rehabilitated area from 0.29 MG to 0.17 MG. The I/I removal project will eliminate predicted overflows with no other improvements required.

An alternative to the I/I removal project is to upsize approximately 319 feet of 10-inch diameter pipe between S69W__011MH and S71W__005MH east of Portal Street to 12 inches to ensure no overflow during the 2-year storm. The estimated construction cost for this alternative is $225,000 in 2008 dollars, approximately $12,000 less than that of the I/I removal project. However, to accommodate the 5-year design storm, additional pipe upsizing is required in addition to completing the pipe upsizing project described above. In comparison, the model predicts that no additional improvements will be required in this area to accommodate the 5-year storm upon completion of the I/I removal project. It is also understood that an extensive I/I removal in this area will produce less peak flow and alleviate flow restrictions in the downstream basin. Hence, it is recommended to remove inflow and infiltration versus increasing pipe size.

DU07

The Dundalk Sewershed model predicts an overflow at manhole S69M__006MH on a section of 8-inch diameter pipe along Dundalk Avenue which connects to a downstream 12-inch diameter pipe on Boston Street. Basin DU07 also has elevated RDII and dry weather base infiltration rates corroborated by CCTV inspection and smoke testing. It is recommended to remove the I/I in sub-catchment 29-02-10-00A by rehabilitating all manholes upstream of manhole S69M__006MH at the intersection of Dundalk Avenue and German Hill Road and lining (CIPP) all pipes in this area. The construction cost for this project is estimated to be $404,000 in 2008 dollars.

Following the completion of this project, the 2-year RDII for the rehabilitated area is reduced to 0.07 MG from 0.12 MG. The I/I removal project will eliminate predicted overflows with no other improvements required.

An alternative to this I/I removal project is to upsize approximately 509 feet of 8-inch diameter pipe between manhole S69O__006MH and manhole S69M__030MH on Dundalk Avenue to 10 inches. The construction cost for this project is estimated to be $358,000 in 2008 dollars. This alternative can save the City approximately $46,000; however, additional pipe upsizing is required to accommodate the 5-year storm. In comparison, the model predicts that no additional improvements will be required in this area to accommodate the 5-year storm upon completion of the I/I removal project. Therefore, it is recommended to remove I/I versus increasing pipe size.

Dundalk Pump Station/Force Main

The Dundalk Pump Station has four (4) variable frequency drive (VFD) pumps, of which only three pumps are constantly online and the 4th pump is for backup use only. The Dundalk Pump Station has enough capacity to handle peak flow from the 2-year, 24 hour storm. However, the velocities in the 36-inch force main were found slightly over 7 fps during peak rain (peak velocity 7.1 fps), and according to the BaSES manual, 7 fps is deemed excessive and may cause a scouring effect.

As mentioned in Section 4.8, a total of 3,852 feet of the Dundalk Force Main using the Sahara® Leak Location System has been inspected. The inspection identified no leaks or gas pockets in the inspected sections. According to Section 8.1.7 of the BaSES manual, assets of the collection system should be inspected and their condition should be assessed periodically. Assuming fair condition of the force main at this time, it is recommended to inspect the force main every 5 years to assess its general condition and detect corrosion and other damages due to the scouring effect.

Another alternative is to build a parallel 8-inch diameter, 4,000 feet force main from the Dundalk Pump Station to manhole S67S__019MH at the intersection of Danville Avenue and Charlotte Avenue. The cost for this alternative is estimated to be $1,530,000 in 2008 dollars. Due to the cost and difficulties in construction, this alternative is not recommended.

Based on the above discussions, the total estimated cost of the recommended 2-year improvements is $642,000 in 2008 dollars and will eliminate a flood volume of 2,500 gallons under the 2-year storm.

5-Year Storm Improvements

Map 5.4.2 at the end of this section, shows the locations and conditions of areas needing improvements for the 5-year storm event in addition to the 2-year improvements. These areas are summarized below.

DU03

Under the 5-year, 24-hour storm, the model predicts an overflow at manhole S63I__017MH on a section of sewer along Eastern Avenue. The overflowing manhole lies at the downstream end of a pipe with a steep slope and is susceptible to flooding under heavy flow. The upstream area of the overflowing manhole includes a residential area with defective cleanouts, deteriorated pipes/manholes, and storm drain connections confirmed by CCTV inspections and smoke testing. To eliminate the predicted overflow, it is recommended to remove the I/I in sub-catchment 29-01-09-00E by disconnecting storm drains, rehabilitating all manholes upstream of manhole S65G__018MH at the intersection of Elrino Street and Eastern Avenue and lining (CIPP) all pipes in this section. The construction cost for this project is estimated to be $213,000 in 2008 dollars.

Removing I/I will reduce 5-year RDII in the rehabilitated area from 0.06 MG to 0.04 MG.

An alternative to removing the I/I is to upsize approximately 361 feet of 10-inch diameter pipe between manhole S63I__003MH and manhole S63I__007MH east of Umbra Street to 12 inches. The estimated construction cost for this improvement is $254,000 versus the I/I removal cost of $213,000 in 2008 dollars. Due to the cost of upsizing the pipes, the I/I removal is recommended.

DU06

The model predicts three (3) new overflows on a section of pipe which begins as a 15-inch diameter pipe, decreases to 12 inches, and then connects to a 27-inch diameter pipe along Dundalk Avenue. This section of pipe receives flow from BDU01; a County basin that has the highest RDII rates based on Dundalk Sewershed I/I analysis. During the 5-year storm, the high flow from BDU01, along with high levels of RDII in basins DU06 and DU07, causes significant surcharge in the interceptor along Dundalk Avenue all the way to the Dundalk Pump Station and leads to the predicted overflows.

The 12-inch diameter pipe described above restricts flow and must be upsized to 15-inch diameter. It is also recommended to perform a comprehensive I/I removal program for areas in basin DU06 that were not rehabilitated under the 2-year storm event including SSAs 29-02-07-00, 29-02-08-00, 29-02-09-00, and sub-catchment 29-02-06-00D. Lastly, it is recommended to perform a comprehensive I/I removal program for four sub-catchments in basin DU07: 29-02-11-00A, 29-02-11-00B, 29-02-11-00C, and 29-02-10-00B. The total estimated construction cost for the proposed projects is $4,190,000.

Another alternative would be for the City to negotiate with the County to reduce RDII in basin BDU01 because reducing the I/I from BDU01 may consequently reduce the amount of improvements required within the City. The County shares a cost in any recommended sewerage facilities that are jointly used.

Removing I/I will reduce 5-year RDII in the rehabilitated area from 1.2 MG to 0.7 MG.

An alternative to removing the I/I is to increase the pipe size of approximately 2,560 feet of the existing 27-inch diameter pipes between S71S__004MH on Dundalk Avenue and S71Y__004MH close to Tributary Street to 30-inch diameter. For this alternative, it is required to also upsize approximately 2,353 feet of existing 30-inch diameter pipes between S71A1_006MH on Oak Avenue and S69C1__013MH on Edgewater Street to 33-inch diameter. This alternative does not eliminate the need to upsize the previously mentioned 12-inch diameter pipe between manhole S71S__005MH and manhole S71S__004MH on Dundalk Avenue to 15-inch diameter. The estimated cost for this alternative is $10,440,000 in 2008 dollars.

A third alternative, would be the installation of an offline storage facility near the City/County boundary. The capacity of the storage tank will need to be 1.2 MG to accommodate the flow from basin BDU01 under the 5-year storm. It is noted that the overflowing area near the City/County line is in a residential neighborhood therefore there might be difficulty obtaining land to place the storage tank. The estimated cost for this alternative is approximately $10,220,000 in 2008 dollars.

In comparison with the proposed I/I removal project, these two options (increasing pipe sizes and installation of a storage tank) are more costly. Based on the estimated costs of these improvements, I/I removal is the recommended alternative.

Dundalk Pump Station/Force Main

Under the 5-year, 24 hour storm, the three main pumps have enough capacity to handle the peak flow. The peak velocity in the 36-inch force main reaches 8.2 fps, rendering the force main not in compliance with velocity threshold of 7 fps. Since the velocity threshold is exceeded only for a short period of time, it is recommended to inspect the force main every 5 years to ensure its structural integrity and normal functioning. Another alternative is to build a parallel 18-inch, 4,000-foot force main from the Dundalk Pump Station to manhole S67S__019MH. The cost for this project is estimated to be $3,320,000 in 2008 dollars. Due to the high cost and difficulties in construction, this alternative is not recommended.

Based on the above discussions, the total estimated cost of the recommended 5-year improvements is $5,050,000 in 2008 dollars and the improvements will eliminate a flood volume of 135,600 gallons under the 5-year storm.

10-Year Storm Improvements

Map 5.4.3 found at the end of this section, shows the locations and conditions of areas needing improvements for the 10-year storm event in addition to the 5-year improvements. These areas are summarized below.

DU01

The model predicts an overflow on a section of 15-inch diameter pipe located just east of South Newkirk Street, between Holabird Avenue and Keith Avenue. The overflowing manhole S61W__007MH and the manhole immediately upstream (S61W__006MH) are shallow and therefore susceptible to flooding during large storm events. This section of pipe was not televised during the time of the study due to construction activities related to the Chesapeake Commerce Center project (old General Motors plant). In addition, manholes along the section of pipe have not been rated. Therefore, the severity of I/I in this area can not yet be determined. It is recommended to verify field conditions (e.g. rim elevation), fully televise this section of pipe and inspect all manholes upon completion of the Chesapeake Commerce Center project to determine if either sealing, or raising the two shallow manholes or I/I removal is an appropriate approach. To eliminate the overflow without completing additional field work, the 15-inch diameter pipe between manhole S61Y__009MH and manhole S59Y__001MH east of Newkirk Street needs to be upsized to 18-inch diameter. The estimated cost for the proposed project is $348,000 in 2008 dollars.

DU03

The same overflow predicted under the 5-year storm occurs under the 10-year storm even after completing the recommended 5-year improvements. It is recommended to perform an I/I removal project for sub-catchment 29-01-09-00C by lining pipes and rehabilitating manholes between manhole S63I__005MH and manhole S65I__008MH on Eastern Avenue, and north of manholes S63I__008MH and S65I__010MH on the two streets perpendicular to Eastern Avenue. CCTV inspection indicate that pipe sections in this area are in poor condition and smoke testing identified defects on some sections of pipes in this area.

Upon completion of the above recommendations, the predicted overflow at manhole S63I__017MH on Eastern Avenue still exists. Therefore, additional work is needed. It is recommended to upsize the existing 10-inch diameter pipe between manhole S63I__007MH and manhole S63I__003MH east of Umbra Street to 12-inch diameter. Or, perform an I/I removal for sub-catchment 29-01-09-00D by rehabilitating all manholes and pipes on Drew Street and Cornwall Street, and also between manhole S65I__008MH and manhole S65G__018MH on Eastern Avenue. The CCTV inspection indicates that the pipes and manholes at this site are in fair to good condition, therefore, I/I removal in this area will not produce significant results required to eliminate the overflow. Hence, the residential area rehabilitation option is not recommended. The I/I removal project and pipe upsizing will together eliminate predicted overflows with no other improvements required.

An alternative to I/I removal with pipe upsizing is to increase the pipe size of approximately 693 feet of the existing 10-inch diameter pipes between manholes S63I__007MH and S63I__006MH east of Umbra Street to 12-inch diameter pipes. The estimated cost for this project is $487,000 compared to I/I removal and 361 feet of 12-inch sewer replacement cost of $431,000 in 2008 dollars. Therefore, the recommended option to eliminate the predicted overflow is I/I removal combined with the upsizing of 361 feet, 10-inch diameter pipe to 12 inches as described above.

DU06

In this basin, the same overflows predicted under the 5-year storm occur under the 10-year storm even after completing the recommended 5-year improvements. For this basin, it is recommended to complete an extensive I/I removal program as well as increase the diameter of various sections of pipes.

The extensive I/I removal program is specifically recommended for SSAs 29-02-13-00 and 29-02-12-00 upstream in basin DU07 that were not rehabilitated under conditions of the 5-year storm event, beginning at the most downstream manhole S69M__027MH on Dundalk Avenue and proceeding upstream.

It is further recommended to increase the pipe diameter from 15 inches to 18 inches of the section of pipe receiving flows from BDU01, beginning at manhole S71S__014MH and ending at manhole S71S__004MH south of Railway Avenue. In addition, approximately 1,900 feet of 27-inch diameter pipes between manhole S71U__010MH on Dundalk Avenue and manhole S71Y__004MH close to Tributary Street will need to be upsized to 30 inches. The I/I removal project and the pipe upsizing will eliminate predicted overflows with no other improvements required. The estimated cost for this recommendation is $5,420,000 in 2008 dollars.

An alternative to the above recommendation is to increase the size of several sections of pipes in this area. First, the section of 15-inch diameter, 530 feet pipe receiving BDU01 flows described above must be upsized to 18 inches. Further, it is required to increase the pipe size of approximately 2,560 feet of the 27-inch diameter pipes between S71S__004MH on Dundalk Avenue and S71Y__004MH close to Tributary Street to 30 inches. Lastly, it is required to upsize approximately 1,880 feet of existing 30-inch diameter pipes between S71A1_008MH on Pipe Avenue and S69C1_013MH on Edgewater Street to 33 inches. The estimated cost for this alternative is $9,760,000.

A third alternative, would be the installation of a 1.4 MG storage tank upstream of the overflowing manholes near the City/County boundary. The cost of this alternative is estimated to be $11,930,000 in 2008 dollars. As discussed in the 5-year Storm Improvement for DU06, difficulty of placing such a storage tank in a residential area makes this alternative less favorable. Therefore, it is recommended to perform I/I removal in combination with increasing pipe diameters. It is also recommended for the City to negotiate with the County to reduce I/I in BDU01 since elevated flows from BDU01 is a major cause of predicted overflows in DU06.

Dundalk Pump Station/Force Main

Under the 10-year, 24 hour storm, the three main pumps have enough capacity to handle the peak flow. The peak velocity in the 36-inch force main increases to 9.6 fps, rendering the force main out of compliance with velocity threshold of 7 fps during peak rain. It is recommended to inspect the force main every 5 years to ensure its structural integrity and normal functioning. An alternative to this is to build a parallel 27-inch, 4000-foot force main from the Dundalk Pump Station to manhole S67S__019MH. The cost for this project is estimated to be $8,180,000 in 2008 dollars. Due to the high cost and difficulties in construction, this alternative is not recommended.

Based on the above discussions, the total estimated cost of the recommended 10-year improvements is $11,150,000 in 2008 dollars and the improvements will eliminate a flood volume of 333,200 gallons under the 10-year storm.

15-Year Storm Improvements

Map 5.4.4 at the end of this section, shows the locations and conditions of areas needing improvements for the 15-year storm event in addition to the 10-year improvements. These areas are summarized below.

DU01

Under the 15-year, 24-hour storm, the model predicts two overflowing manholes: S61W__006MH and S61W__007MH east of Newkirk Street. It is recommended to upsize approximately 321 feet of 15-inch diameter pipes between S61Y__009MH and S61Y__A01MH east of Newkirk Street to 18 inches. The estimated construction cost for this upgrade is $267,000 in 2008 dollars.

As mentioned previously, either an I/I removal program or raising the two shallow manholes or simply sealing the two manholes could be more cost effective to eliminate the predicted overflows. Hence, it is worthwhile to verify field conditions, fully televise this section of pipe and inspect all manholes upon completion of the Chesapeake Commerce Center project.

DU03

The same overflow predicted under the 5-year and 10-year storms occurs under the 15-year storm even after completing the recommended 10-year improvements. It is recommended to upsize the 10-inch diameter pipe between manhole S63I__003MH and S63I__006MH east of Umbra Street to 12 inches. The cost for this upgrade is estimated to be $233,000 in 2008 dollars.

DU05 and DU06

Overflows on the section of 8-inch diameter pipe along Portal Street and on the section of pipe receiving BDU01 flows occur again under the 15-year storm after completing the recommended 10-year improvements. In addition to these, the model predicts three new overflows on a section of 8-inch pipe through Ft. Holabird Park. It is recommended to upsize the 10-inch diameter pipe between S69W__011MH and S71W__005MH east of Portal Street to 12 inches. In addition, approximately 652 feet of existing 27-inch diameter pipes between S71S__004MH and S71U__010MH on Dundalk Avenue need to be increased to 30 inches. Lastly, approximately 1,880 feet of existing 30-inch diameter pipes in basin DU05 between S69C1__013MH on Edgewater Street and S71A1__008MH on Pine Avenue need to be increased to 33-inch diameter. The estimated construction cost for this recommendation is $5,650,000 in 2008 dollars.

Construction of the proposed pipe upsizing between S71S__004MH and S71U__010MH on Dundalk Avenue may be difficult due to traffic and other existing utilities. Such work may not be required if the I/I from County basin BDU01 can be reduced by 40%.

An alternative to increasing pipe diameters is to install a 1.5 MG storage tank to accommodate the peak flow from basin BDU01 during the 15-year storm event. The estimated cost of this alternative is $12,780,000 in 2008 dollars. This alternative is not recommended due to the difference in cost of $7,130,000, compared to cost of pipe upsizing described above.

DU07

The overflow previously depicted in the 2-year improvement, at manhole S69M__006MH on German Hill Road occurs again under the 15-year, 24 hour storm even after completing the recommended 2-year improvements. For the 15-year storm event, approximately 283 feet of an existing 8-inch diameter pipe between S69O__006MH and S69O__007MH on Dundalk Avenue is recommended to be upsized to 10 inches. The cost for this upgrade is estimated to be $199,000 in 2008 dollars.

Dundalk Pump Station/Force Main

Under the 15-year, 24 hour storm, the three main pumps have enough capacity to handle the peak flow. The peak velocity in the 36-inch force main increases to 10.1 fps, rendering the force main not in compliance with velocity threshold of 7 fps during peak rain. It is recommended to inspect the force main every 5 years to ensure its structural integrity and normal functioning. An alternative to this is to build a parallel 27-inch, 4000-foot force main from the Dundalk Pump Station to manhole S67S__019MH. The cost for this project is estimated to be $8,180,000 in 2008 dollars. Due to the high cost and difficulties in construction, this alternative is not recommended.

Based on the above discussions, the total estimated cost of the recommended 15-year improvements is $17,500,000 in 2008 dollars and the improvements will eliminate a flood volume of 468,700 gallons under the 15-year storm.

20-Year Storm Improvements

Map 5.4.5 at the end of this section, shows the locations and conditions of areas needing improvements for the 20-year storm event in addition to the 15-year improvements. These areas are summarized below.

DU01

The model predicted a small amount of overflow at a shallow manhole S61W__006MH, east of Newkirk Street. As discussed previously, the overflow can be eliminated by simply sealing this manhole or elevating the manhole rim elevation 2.1 feet if field conditions allow. As an alternative, the pipe diameter of the 15-inch pipe between S61Y__A01MH and S61Y__A02MH east of Newkirk Street may be increased to 18 inches. The estimated cost for this alternative is $223,000 in 2008 dollars.

DU03

Manhole S65I__001MH on Eastern Avenue floods during the 20-year storm event even after completing the recommended 15-year improvements. To eliminate the overflow, it is recommended to upsize 260 feet of the existing pipe between manhole S63I__006MH and manhole S63I__017MH on Eastern Avenue from 10-inch diameter to 12 inches. The cost for this upgrade is estimated to be $183,000 in 2008 dollars.

DU05 and DU06

Overflows occur on the section of pipe receiving flows from BDU01 and on the section of pipe through Ft. Holabird Park during the 20-year storm after the completion of the 15-year recommendations. It is recommended to upsize approximately 2,164 feet of the 30-inch diameter pipes between manholes S71W__007MH east of Portal Street and S71A1__008MH on Pine Avenue to 33 inches. It is also recommended to raise six (6) manholes on the pipe section through Ft. Holabird Park: raising manholes S69A1_017MH, S69A1_019MH and S71A1_017MH by 2.0 feet and raising manholes S69A1_012MH, S69A1_016MH, S69A1_018MH by 1 foot. The cost for this upgrade is estimated to be $4,730,000 in 2008 dollars.

Dundalk Pump Station/Force Main

During the 20-year, 24 hour storm event, the three main pumps do not have enough capacity to handle the peak inflow into the pump station after completing improvements recommended to this point, rendering the flooding of the wet well. It is recommended to turn on the 4th pump (i.e., the backup pump) to eliminate this projected overflow. In the case that the backup pump is offline for maintenance, one alternative is to install a 0.02 MG storage tank near the Dundalk Pump Station to attenuate the peak flow entering the wet well. The estimated cost for this alternative is $170,000 in 2008 dollars based on a unit cost of $6 per gallon of storage.

An alternative to installation of a storage tank is to upgrade the force main. Notably, a project was completed in 1997 on a section of Dundalk Force Main near 6200 to 6300 Beckley Street. A new 36 inch diameter ductile iron bypass was installed and the new line runs parallel at approximately 12 feet to the west of the old line. The old line was capped and abandoned when the bypass was installed. There are Four (4) 90 degree bends and two 24 inch connection pipes between the new and the old 36 inch lines. These bends and connections restrict flow in the system and leads to the SSO at the wet well. The model predicts that if the abandoned 36 inch line is reactivated, the projected SSO at the wet well will be eliminated. Since this line was abandoned, it was not internally inspected as part of the Paragraph 9 requirements of the CD. Internal inspection of the section of sewer and further upgrade (if necessary) should be performed prior to reactivation. The cost for this alternative is $155,000 in 2008 dollars. This alternative can save the City approximately $15,000 compared to installation of a 0.02 MG storage tank. Hence, it is recommended to reactivate the abandoned line.

The peak velocity in the force main is also slightly above 10 fps regardless of the aforementioned improvements, rendering the force main out of compliance with velocity threshold of 7 fps. It is recommended to inspect the force main every 5 years to ensure its structural integrity and normal functioning. An alternative to this is to build a parallel 27-inch, 4000-foot force main from the Dundalk Pump Station to manhole S67S__019MH. The cost for this project is estimated to be $8,180,000 in

2008 dollars. Due to the high cost and difficulties in construction, this alternative is not recommended.

Based on the above discussions, the total estimated cost of recommended 20-year improvements is $20,900,000 in 2008 dollars and the improvements will eliminate a flood volume of 611,900 gallons under the 20-year storm.

The total estimated improvement costs per design storm return period are presented in **Table 5.4.1**. The total estimated improvement costs to eliminate each gallon of predicted overflow per design storm period are presented in **Table 5.4.2**. These tables show the incremental cost to convey each year storm event flows and the cumulative cost from the previous years.

Table 5.4.1
Dundalk Sewershed Study and Plan: Hydraulic Modeling
Total Estimated Improvement Costs for Dundalk

Project Year	2-year Storm	5-year Storm		10-year Storm		15-year Storm		20-year Storm	
		Incremental	Cumulative	Incremental	Cumulative	Incremental	Cumulative	Incremental	Cumulative
2008	$642,000	$4,410,000	$5,050,000	$6,100,000	$11,150,000	$6,350,000	$17,500,000	$3,400,000	$20,900,000
2009	$687,000	$4,710,000	$5,400,000	$6,530,000	$11,930,000	$6,790,000	$18,720,000	$3,650,000	$22,370,000
2010	$735,000	$5,050,000	$5,780,000	$6,980,000	$12,760,000	$7,270,000	$20,030,000	$3,900,000	$23,930,000
2011	$786,000	$5,400,000	$6,190,000	$7,470,000	$13,660,000	$7,780,000	$21,440,000	$4,170,000	$25,610,000
2012	$841,000	$5,780,000	$6,620,000	$7,990,000	$14,610,000	$8,330,000	$22,940,000	$4,460,000	$27,400,000
2013	$900,000	$6,180,000	$7,080,000	$8,560,000	$15,640,000	$8,900,000	$24,540,000	$4,780,000	$29,320,000
2014	$963,000	$6,620,000	$7,580,000	$9,150,000	$16,730,000	$9,530,000	$26,260,000	$5,110,000	$31,370,000
2015	$1,031,000	$7,080,000	$8,110,000	$9,790,000	$17,900,000	$10,200,000	$28,100,000	$5,470,000	$33,570,000
2016	$1,103,000	$7,580,000	$8,680,000	$10,480,000	$19,160,000	$10,910,000	$30,070,000	$5,850,000	$35,920,000
2017	$1,180,000	$8,100,000	$9,280,000	$11,220,000	$20,500,000	$11,670,000	$32,170,000	$6,260,000	$38,430,000

Table 5.4.2
Dundalk Sewershed Study and Plan: Hydraulic Modeling
Total Estimated Improvement Costs per Gallon of SSO Removed

Project Year	2-year Storm	5-year Storm		10-year Storm		15-year Storm		20-year Storm	
	SSO 2,500 gal	SSO 135,600 gal		SSO 333,200 gal		SSO 468,700 gal		SSO 611,900 gal	
		Incremental	Cumulative	Incremental	Cumulative	Incremental	Cumulative	Incremental	Cumulative
2008	$257	$33.1	$37.2	$30.9	$33.5	$46.9	$37.3	$23.7	$34.2
2009	$275	$35.4	$39.8	$33.0	$35.8	$50.1	$39.9	$25.5	$36.6
2010	$294	$37.9	$42.6	$35.3	$38.3	$53.7	$42.7	$27.2	$39.1
2011	$314	$40.6	$45.6	$37.8	$41.0	$57.4	$45.7	$29.1	$41.9
2012	$336	$43.4	$48.8	$40.4	$43.8	$61.5	$48.9	$31.2	$44.8
2013	$360	$46.4	$52.2	$43.3	$46.9	$65.7	$52.4	$33.4	$47.9
2014	$385	$49.7	$55.9	$46.3	$50.2	$70.3	$56.0	$35.7	$51.3
2015	$412	$53.2	$59.8	$49.5	$53.7	$75.3	$60.0	$38.2	$54.9
2016	$441	$56.9	$64.0	$53.0	$57.5	$80.5	$64.2	$40.9	$58.7
2017	$472	$60.9	$68.4	$56.8	$61.5	$86.1	$68.6	$43.7	$62.8

6.0 Geographic Information System (GIS)

6.1 Overview of GIS

The City of Baltimore maintains a Geographic Information System (GIS) representing the wastewater infrastructure. The GIS is housed in an ESRI format Geodatabase and leverages the enterprise capabilities of ArcSDE. An integral part of the sewershed study is updating the GIS to represent the existing conditions at the time of the study. These updates provided to the City were considered "Core" data deliveries as they are the primary or core repository of data representing the wastewater infrastructure. This is in comparison to "non-core" data which was the supplemental data provided to the City such as manhole inspection reports, CCTV video, etc.

This section describes the City's GIS system, the methods and procedures used during the project to update the system, and the quality assurance procedures performed to verify the accuracy of the data.

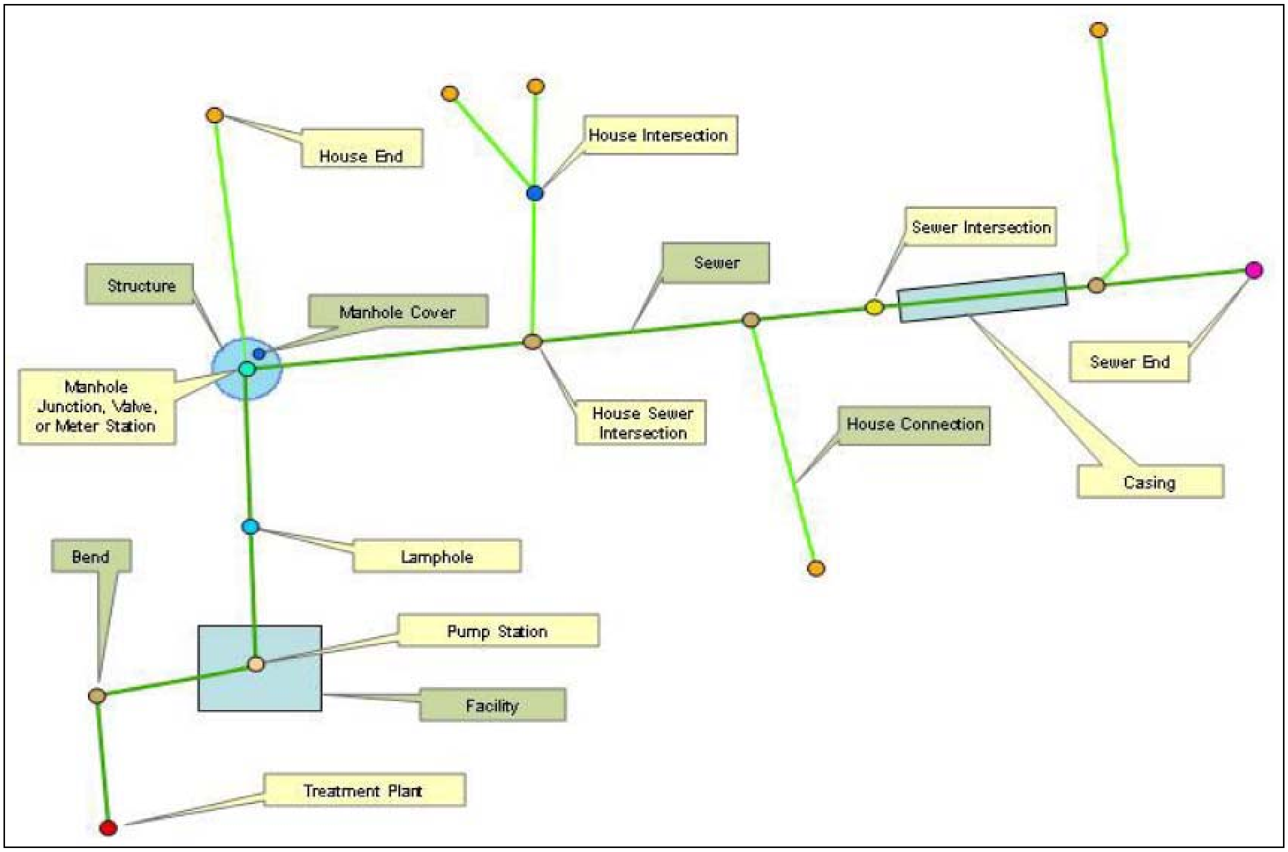
The wastewater utility Geodatabase is comprised of three thematic groups of features:

- Lines Thematic Group – contains wastewater features that can be represented as lines whose direction indicates the direction of flow. These line features make up the foundation of the wastewater network. All features in this thematic group participate in the geometric network. These features include:
    - House Connection (line)
    - Sewer (line)

- Features Thematic Group – contains wastewater features that can be represented as points, lines and/or polygons. The features in this thematic group do not affect flow and will not participate in the geometric network. Traces and other network analysis operations do not consider these entities, yet they are captured in the database to provide a more complete representation of the system. These features include:
    - Facility (polygon)
    - Manhole Cover (point)
    - Structure (polygon)

- Devices Thematic Group – contains wastewater features that can be represented as points. All features in this thematic group participate in the geometric network. These features include:
    - Manhole Junction (point)
    - Meter Station (point)
    - Pump Station (point)
    - Bend (point)
    - Valve (point)
    - House End (point)
    - House Intersection (point)
    - House Sewer Intersection (point)
    - Sewer End (point)
    - Sewer Intersection (point)

The following graphic, provided in BaSES Section 5, summarizes the feature objects in the City's wastewater GIS.



6.2 Field Data and GIS Integration

The Sewershed Study and Evaluation project involved extensive field activities which generated significant amounts of non-core data to be used to update the core GIS data. Specifically, the non-core data generated was:

- Manhole Inspection Data
- GPS Survey Data
- Closed Circuit Television (CCTV) Inspection Data
- Smoke and Dye Testing Data

The majority of the spatial and attribute edits made to the wastewater geodatabase were based on information extracted from these non-core datasets. When current conditions could not be established through these sources, additional engineering contract document research was performed to populate the GIS. The following is further description regarding the field collected data and its use in updating the GIS.

Manhole Inspections

Manhole inspections were performed on 545 manholes in the Dundalk Sewershed. Information was collected using a custom designed application, Manhole Inspection Application Software (MIAS). MIAS allows field crews to collect detailed information about the physical characteristics of a manhole, its sewer connections, and the surrounding environment. In addition, the application records the condition and infiltration properties of the manhole. The MIAS application stores inventory and condition information for the following manhole components:

- Location
- Environment
- Cover
- Frame
- Chimney/Stack
- Corbel
- Barrel
- Bench
- Channel
- Pipe Connections and Sizes

The unique identifier used in both the GIS and MIAS datasets is the MANHOLE_ID field. This common field allows for integration of the manhole inspection field information directly into wastewater feature attribute fields. In addition to data collected in the MIAS application, inspectors also recorded changes between actual field conditions and the current GIS, such as pipe sizes and pipe material.

As part of the manhole inspection process, field crews verified the horizontal location of the manholes by using survey-grade GPS.

Roughly 4,110 manhole inspection photos were taken during the Dundalk Sewershed inspection. The MIAS application provided easy access to these photos for use in checking and validating the manhole information being entered into the database.

GPS Survey Data

A total of 161 survey-grade GPS survey locations of manhole covers were completed during the project. These GPS locations were used to position key manhole features and to establish the rim elevation stored in the manhole cover GIS feature class, as well as provide accurate rim elevations for the model.

The GPS rim elevations were used along with depths measured during the manhole inspection, from the rim down to the invert of each pipe connecting manhole, to establish pipe invert elevations in the Sewer feature layer.

Rim elevations for manholes that were not GPS surveyed were extracted and calculated through research of engineering drawings.

CCTV Inspection Data

The Dundalk Sewershed CCTV consultants, as part of the GIS efforts, completed roughly 703 individual CCTV sewer inspections. The up and down nodes for each CCTV survey were verified to ensure that they link to valid GIS Manhole Junction or Sewer End features that represent the starting and ending locations of the survey.

With the data relationship established, the CCTV surveys, manhole inspections (MIAS database) and the GIS were compared to assist in GIS attribute updating.

The CCTV surveys were invaluable in the GIS updating process by enabling Engineers and GIS technicians to perform the following:

- Establish the existence of manholes in the GIS
- Locate previously unknown buried manholes and incorporate them into the GIS at their proper location
- Confirm the absence of manholes that were either removed or never existed to begin with and were erroneously still included in the GIS
- Identify the proper location of changes or fixtures in the system

6.3 Office Research and GIS Updates

The combination of field collected data allowed GIS technicians to update a significant amount of the GIS representation of the wastewater infrastructure. Prioritization of the applicability of the variety of sources was performed on an attribute by attribute basis based upon the guidance provided by the City's BaSES manual. Some features or attributes could not be adequately populated using the collected field information and required additional research of Baltimore's record plat maps and engineering contract drawings, in conjunction with the Automated Image Retrieval System (AIRS) organizational application provided by the City.

Using standard ESRI editing functionality in the ArcGIS platform as well as custom tools for GIS updates, GIS technicians utilized the sources available to them to update the wastewater geodatabase. As tiles in the City's standard grid index were completed and quality assurance approved, the data was synchronized back to the City using Tadpole's GoSync software for quality control review by the data clearinghouse.

6.4 QA/QC Review and Procedures

A variety of procedures were performed for quality assurance and quality control of the wastewater geodatabase, including the following:

- Oversight and manual spot checks.
- Database queries to compare the GIS datasets with the other non-core data sources.
- An automated suite of 171 quality control tests provided by the City and built in the ESRI Production Line Tool Set (PLTS) platform were run against the dataset both by the sewershed consultant as well as the data clearinghouse. These tests perform a variety of checks on features and feature attributes, including: domain validation, attribute, logical, spatial, and topologic.

6.5 GIS Certification

RJN has followed the processes described above and those described in more detail in the City's BaSES manual to update the City of Baltimore's wastewater GIS for the Dundalk Sewershed.

The City of Baltimore and RJN are hereby certifying that the GIS data represented in the Dundalk Sewershed portion of the City's GIS provides the necessary data for the adherence of Paragraph 14, Information Management System Program of the CD.

The Dundalk Sewershed portion of the City's GIS is the best assessment of current conditions achievable with the available technology and source data. Current conditions are defined as of 02/15/2010. Furthermore, the City of Baltimore has instituted processes to ensure that, should changes to the sewer infrastructure in the Dundalk Sewershed occur; the GIS will be updated within 90 days of the changes.

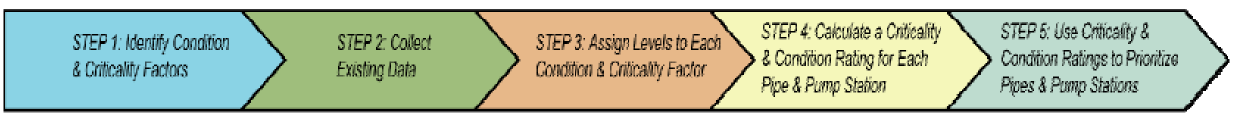
7.0 Recommendations

As required by the Consent Decree (CD), each Sewershed Study and Plan must identify specific improvements or other corrective actions needed to address the deficiencies identified during the sewershed evaluation to aid in reducing RDII contributing to Sanitary Sewer Overflows (SSOs), address deficiencies identified during the hydraulic analyses, and address other deficiencies that contribute to SSOs in the sewershed. This section outlines how the data analysis, evaluation, and decision-making criteria were utilized to identify and prioritize improvements for the Dundalk Sewershed.

7.1 Decision Making Criteria

As part of the sewershed studies, the City developed a condition and criticality protocol that provides a framework for a continuous rehabilitation strategy of all collection system components based on both criticality (consequence of failure) and condition (probability of failure). Assets whose failure can have large impacts on the community and the environment and whose condition is the poorest will receive a higher criticality rating and will receive immediate attention. Assets that receive lower criticality rating will receive some level of continued monitoring but no immediate action or rehabilitation at this time.

The prioritization process as outlined in BaSES Section 8, consists of five steps illustrated below



Step 1 - Identify the condition and criticality factors that will be used to assess the sewer system. These factors have been identified to include proximity to human population, to bodies of water, to forests, and to wildlife habitat that could potentially be affected by a sewer system failure.

Step 2 – Collect data that will be used to evaluate each factor including CCTV inspection data, manhole inspection data, pump station inspection data, GIS data, results of hydraulic modeling, and sewer complaint data.

Step 3 – Assign different levels to each factor so that pipes, manholes, and pump stations can be differentiated in terms of their condition or criticality.

Step 4 – Assign a condition and criticality rating for each pipe, manhole, and pump station. The ratings are assigned by using the level assigned to each factor and the relative importance of each factor.

Step 5 – Use the ratings to prioritize the system and determine short-term and long-term rehabilitation projects.

For each category, various factors will be used to measure the criticality and condition for every asset. **Table 7.1.1** lists the condition and criticality categories and factors that were considered.

Table 7.1.1
Dundalk Sewershed Study and Plan: Sewershed Recommendations
Condition and Criticality Factors

Criticality Category	Criticality Factor
Quantity of Flow Conveyed	Pipe Diameter
	Pump Station Capacity
Transportation/Urban Impact	Proximity to Historic Areas
	Proximity to Community Areas
	Traffic Conditions
	Proximity to Railroads
Environmental Impact	Proximity to Forested Areas
	Proximity to Waterways/Streams
	Proximity to Wetlands
Public Health Impact	Population Density
	Proximity to Floodplain
	Pump Station SCADA/Warning Systems
Ease of Emergency Repair	Accessibility
	Proximity to Conduits
	Building Encroachment
	Pipe Depth
	Ability to Re-Route Flow
	Ability to Bypass Flow
Condition Category	Condition Factor
Structural Condition	PACP Structural Pipe Rating
Maintenance Frequency	PACP O&M Pipe Rating
	Active SSOs
	Known Maintenance Problems
	Need for Additional Capacity
	RDII Values
Capacity	Need for Additional Capacity

Each condition and criticality factor is assigned a rating from 1 to 5. The purpose of assigning ratings to each condition and criticality factor is to differentiate sewer pipes, manholes, and pump stations in terms of the consequences and probability of their failure.

The rating assigned increases as the consequence of failure or probability of failure increases. For example, a break in a 24-inch diameter sewer interceptor can result in more wastewater being released than a break in an 8-inch diameter sewer pipe. Therefore, the larger diameter pipe has a higher criticality rating based on the amount of flow being conveyed. The 24-inch diameter sewer interceptor would be assigned a higher rating of five (5), for the "Quality of Flow Conveyed" criticality factor and the 8-inch diameter sewer pipe would be assigned a lower rating of one (1), for the same factor.

After a rating of 1 through 5 is assigned, an overall criticality rating and an overall condition rating is calculated for each system component. The criticality rating is calculated using the highest individual level assigned to any of the criticality factors multiplied by a relative importance value. The condition rating is equal to the highest individual National Association of Sewer Service Companies (NASSCO) Pipeline Assessment and Certification Program (PACP) or Manhole

Assessment and Certification Program (MACP) rating assigned to any of the condition factors. The relative importance value for the criticality rating is the weighting, expressed as a percentage, applied to each criticality factor to calculate an overall rating. The relative importance values are the same for each collection system component and are presented in Table 7.1.2.

Table 7.1.2

Dundalk Sewershed Study and Plan: Sewershed Recommendations

Criticality Factor Relative Importance Values

Criticality Factors	Relative Importance Value
Quantity of Flow Conveyed	30%
Transportation/Urban Impact	15%
Environmental Impact	20%
Public Health Impact	15%
Ease of Emergency Repair	20%
Total:	100%

The final assessment results in individual ratings for condition and criticality on a scale of 1 through 5, which determines priorities for repairs or continuous condition assessment or monitoring. This approach allows the City to focus their available resources and funding on the most immediate system repair needs. Figure 7.1.1 is a matrix showing the recommended course of action for each sewer system component based on the combination of condition and criticality. The vertical scale,1 through 5, is for condition and the horizontal scale is a rating for an asset's criticality within the collection system.

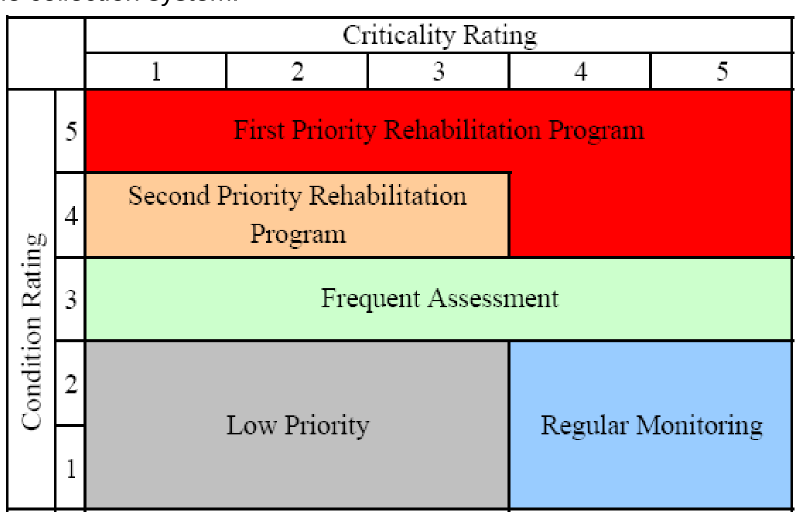


Figure 7.1.1: Condition/Criticality Matrix (BaSES)

Each of the recommended courses of action as defined in BaSES are described in more detail below. The specific improvement projects and/or other corrective actions will vary based on the type of collection system component (gravity sewer, force main, manhole, or pump station).

First Priority Rehabilitation Program

Assets that receive a condition rating of 5 regardless of criticality, and assets that receive a condition rating of 4 and criticality rating of 4 and 5 are placed at the highest priority for rehabilitation, repair, or replacement. These assets lack hydraulic capacity, contribute to system inflow and infiltration (I/I) and/or are likely to fail in the near future. They present the potential for SSOs or could create a major disruption in service and potentially impact the environment and/or public health if not addressed.

Second Priority Rehabilitation Program

Assets that receive a condition rating of 4 and a criticality rating of 1, 2, or 3 will be given second priority in the rehabilitation program. These assets contribute to system I/I, and are likely to continue to deteriorate and require attention in the foreseeable future.

Frequent Assessment

Assets that are in fair physical condition (PACP/MACP condition rating of 3), should have their condition assessed frequently, every 2 to 3 years regardless of the criticality rating. The purpose of frequent assessment is to check if the condition has deteriorated to a point that the asset would need to be moved to a higher priority.

Regular Monitoring

The assets in the regular monitoring category are typically in serviceable condition (PACP/MACP condition rating of 1 or 2), but received a high criticality rating of 4 or 5. These assets should be checked every 3 to 5 years.

Low Priority

The low priority category included assets that are believed to be in good condition (PACP/MACP condition rating of 1 or 2), and received a lower criticality rating of 1 through 3. The assets in this category will receive some level of inspection (once every 5 to 10 years) to verify that their conditions are not continuing to deteriorate.

7.2 Proposed Improvements

It should be noted that the interrelationship between the City's sewersheds, known as boundary conditions, must be understood and carefully considered before significant hydraulic repairs are completed. The Dundalk, Jones Falls, Herring Run, High Level, and Low Level sewersheds flow into the Outfall sewershed. These six sewersheds are connected and hydraulically interdependent, creating "boundary" conditions that must be defined and considered for hydraulic modeling. Ultimately, the collection system within the six interdependent sewersheds should be modeled as one. The City has begun development of a model to accomplish the system-wide modeling, which will be refined and improved as the individual sewershed studies complete calibration of their respective sewershed models. This Plan provides certain recommended improvements that would be implemented by the City in accordance with a proposed schedule. However, this Plan should not be considered final and may require amendments as necessary, once the system-wide hydraulic model is completed and system-wide simulations are performed. System-wide simulations could alter the recommendations identified by an individual Sewershed Study and Plan.

Once the sewer system improvement projects and/or other corrective actions required to address deficiencies were identified and ranked based on the criticality and condition ratings; assets that received a condition rating of 5, regardless of criticality, were included in a "First Priority" corrective action plan. Assets that had a condition rating of 4 and a criticality rating of 4 or 5 were also included in the "First Priority" corrective action plan. Assets that had a condition rating of 4, but were not considered to be as critical (3 or less) were included in the "Second Priority" corrective action plan.

Asset prioritization was developed with consideration that all proposed improvement projects required to eliminate SSOs must be completed before January 1, 2016 as stipulated by the CD. These proposed improvement projects are explained below.

7.2.1 Sanitary Sewer Overflow (SSO) Structure Identification and Elimination

As a requirement of the City's CD, the Sewershed Study and Plan is required to identify undocumented SSO structures. Investigations completed in support of this report have identified no undocumented SSO structure in the Dundalk Sewershed that requires elimination.

7.2.2 Structural Deficiencies Identified

Proposed Manhole Improvements (Condition Rating Grade 4 & 5)
Table 7.2.2.1 shows a listing of all manholes inspected within the Dundalk Sewershed basins based on overall condition ratings. Manholes that require immediate attention were given a rating of 5; these include sewer manholes with Storm drain covers and manholes with offset frames. **Table 7.2.2.2** shows all manholes that received a condition rating score of 4 or 5 and are recommended for repairs.

Table 7.2.2.1
Dundalk Sewershed Study and Plan: Sewershed Recommendations
Overall Condition Ratings for Active Manholes by Basin

Overall Rating	Totals	DU01		DU02		DU03		DU04		DU05		DU06		DU07		TSDU03	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1- Overall Rating	2	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0
2 - Overall Rating	180	6	33	12	20	29	32	22	37	19	28	41	39	44	40	7	23
3 - Overall Rating	348	10	56	46	75	61	66	36	60	45	67	61	58	65	59	24	77
4 - Overall Rating	12	1	6	3	5	1	1	2	3	3	4	1	1	1	1	0	0
5 - Overall Rating	3	1	6	0	0	0	0	0	0	0	0	2	2	0	0	0	0
MH Totals	**545**	**18**		**61**		**92**		**60**		**67**		**105**		**111**		**31**	

Table 7.2.2.2
Dundalk Sewershed Study and Plan: Sewershed Recommendations
Overall Condition Ratings 4 & 5 by Basin

Overall Rating	Totals	DU01		DU02		DU03		DU04		DU05		DU06		DU07		TSDU03	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
4 - Overall Rating	12	1	6	3	5	1	1	2	3	3	4	1	1	1	1	0	0
5 - Overall Rating	3	1	6	0	0	0	0	0	0	0	0	2	2	0	0	0	0
MH's w/ 4/5 Rating	**15**	**2**		**3**		**1**		**2**		**3**		**3**		**1**		**0**	

As discussed previously in Section 4.2, there were a total of 55 manholes in Dundalk Sewershed that could not be inspected due to various reasons and therefore received no structural ratings. These manholes need to be raised to ground surface, opened with special tools, or heavy cleaned before manhole inspection can be performed. It is recommended that the City secure contractors to complete these tasks, perform manhole inspection, and asses these manholes' physical condition. The costs to inspect these manholes are estimated and provided in Section 7.4.1.

Map 7.2.2, found at the end of this section, shows the location of the First and Second Priority manholes and sewers.

Proposed Sanitary Sewer Improvements

Table 7.2.2.3 shows the length of the active sanitary sewers located within the Dundalk Sewershed that were ranked as First and/or Second Priority assets requiring repair. All First and Second Priority sewers received condition ratings of 4 or 5 and are recommended for repairs.

Table 7.2.2.3

Dundalk Sewershed Study and Plan: Sewershed Recommendations

Sanitary Sewer Overall Condition Ratings (4 & 5) by Basin

Overall Rating	Totals		DU01		DU02		DU03		DU04		DU05		DU06		DU07		TSDU03	
	LF	%	LF	%	LF	%	LF	%	LF	%	LF	%	LF	%	LF	%	LF	%
4/5 Overall Rating	28,349	100	11,552	43	297	1	1,466	5	0	0	5,899	22	5,748	21	2,193	8	1,195	4
Total Linear Ft:	**28,349**		**11,552**		**297**		**1,466**		**0**		**5,899**		**5,748**		**2,193**		**1,195**	

There was a total of 28,349 LF of pipe that received a rating of 4 or 5. Approximately 15,400 LF of pipe sections in Dundalk Sewershed have not been CCTV inspected due to high water levels, blockage, and various other access issues as described in Section 4.3 and therefore received no structural and O&M ratings. Of the 15,400 LF of pipes that could not be CCTV inspected, 6,200 LF of pipe sections received an overall condition rating of 4 or 5 due to other condition factors (e.g., high RDII). It is imprudent to recommend an appropriate rehabilitation method for such pipe sections in Tables 7.4.1.2A and 7.4.1.2B prior to CCTV inspection. It is therefore recommended that the City secure contractors capable of heavy cleaning and televising on large, deep sanitary sewers. The costs to CCTV inspect these pipe sections are estimated and provided in Section 7.4.1.

Map 7.2.2, found at the end of this section, shows the location of the First and Second Priority manholes and sewers.

7.2.3 Proposed Hydraulic Improvements (2-Year Storm)

Based on the Baseline Analysis and Capacity Assessment in Attachment 5.3.1, basins DU06 and DU07 require hydraulic improvements to reduce SSOs when conveying a 2-year storm event. In addition, the Dundalk force main requires frequent inspection to ensure its structural integrity. These improvements are listed in details below. Map 7.2.3 at the end of this section, details the locations of the following projects described on a basin level.

DU06

From the Baseline Analysis and Capacity Assessment, there is an estimated total volume of 0.001 MG of overflow during the 2-year, 24-hour storm event in basin DU06, under current conditions. These overflows occur at two locations along a section of 8-inch diameter pipe on Portal Street. Flow monitoring identified Basin DU06 as having the highest capture coefficient and RDII rate (refer to Section 3.7 for details). Also in this basin, several manholes and pipes, including 3 manholes and 2 pipe sections on Dundalk Avenue, are in highly deteriorated condition with a condition rating of 4 or 5 as defined in Section 4.2 of the BaSES manual. It is therefore recommended to perform an extensive inflow/infiltration (I/I) removal project in the area of the overflowing manholes. The I/I removal project will involve rehabilitating all manholes upstream and installing cured in place pipe (CIPP) liners on the pipe sections upstream of manhole S71W__001MH, between Chandlery Street and Tributary Street. This I/I removal project will eliminate predicted overflows with no other improvements required.

DU07

DU07 has an estimated 0.0012 MG of overflow during the 2-year, 24-hour storm event under current conditions. The predicted overflow occurs on a section of 8-inch diameter pipe along Dundalk Avenue which connects downstream to a 12-inch diameter pipe on Boston Street. Basin DU07 also has elevated RDII and dry weather base infiltration rates corroborated by CCTV inspection and smoke testing. An I/I removal project is recommended upstream of manhole S69M__006MH at the intersection of Dundalk Avenue and German Hill Road. The I/I removal project in this area will eliminate the predicted overflow in this basin, with no other improvements required.

Dundalk Force Main

For a 2-year storm or above, Dundalk force main is not in compliance with the velocity threshold of 7 fps specified in the BaSES manual; 7 fps is deemed excessive and may cause a scouring effect. To ensure structural integrity and normal functioning of the force main, a frequent force main inspection is recommended. A force main inspection was completed in 2009 and identified no leaks or gas pockets. Given its fair condition at this point, it is recommended that the City hire a contractor to perform another inspection to have its physical condition re-assessed in 2014. This project falls into the City's re-inspection program (see Section 7.5) and therefore the schedule and cost for Dundalk force main inspection are not reported in Section 7.3 (schedules for proposed improvements) and Section 7.4 (costs for proposed improvement).

7.3 Proposed Improvement Implementation Schedule

An implementation schedule for completion of the proposed SSO elimination and sewer system improvements has been developed as part of this project based on project cost, anticipated project duration, available manpower, and materials. The implementation schedule was developed with consideration that all proposed improvements must be completed before January 1, 2016 as stipulated by the CD. The following schedules have been developed providing time to successfully complete the required work.

Manhole Rehabilitation:

The Schedule provided in Table 7.3.1 represents a reasonable duration required for the City to select an engineering consultant to prepare the required design documents, advertise the project, select a contractor to complete the required repairs and have the effectiveness of the repairs evaluated.

Table 7.3.1

Dundalk Sewershed Study and Plan: Sewershed Recommendations

Manhole Rehabilitation Implementation Schedule (1ST & 2nd Priority)

Paragraph 9 Project	Project	Description	CD Milestone Dates		
			Advertise Project	Construction Completion	Evaluation Phase Completion
1	First Priority Manhole Rehabilitation	Completion of First Priority Manhole Rehabilitation/Replacement Projects Throughout the Dundalk Sewershed	5/1/2012	7/1/2014	7/1/2015
1A	Second Priority Manhole Rehabilitation	Completion of Secondary Manhole Rehabilitation/Replacement Projects Throughout the Dundalk Sewershed	5/1/2012	7/1/2014	7/1/2015

Sanitary Sewer Rehabilitation:

The schedule provided in Table 7.3.2 represents a reasonable duration required for the City to select an engineering consultant to complete the required design documents, advertise the project, select a contractor to complete the work on the sewers and have the effectiveness evaluated.

Table 7.3.2

Dundalk Sewershed Study and Plan: Sewershed Recommendations

Sanitary Sewer Rehabilitation Implementation Schedule (1ST & 2nd Priority)

Paragraph 9 Project	Project	Description	CD Milestone Dates		
			Advertise Project	Construction Completion	Evaluation Phase Completion
2	First Priority Rehabilitation	CIPP, Point Repairs, and Combination CIPP/Point Repairs for First Priority	5/1/2013	10/1/2014	10/1/2015
2A	Second Priority Rehabilitation	CIPP, Point Repairs, and Combination CIPP/Point Repairs for Second Priority	5/1/2013	10/1/2014	10/1/2015

Inspection of Remaining Manholes and Sewers:

The schedule provided in Table 7.3.3 represents a reasonable duration for the City to advertise the project and select contractors to complete inspection of remaining manholes and sewers (refer to Section 7.2.2 for details) and have physical condition and criticality evaluated.

Table 7.3.3
Dundalk Sewershed Study and Plan: Sewershed Recommendations
Sanitary Manhole and Sewer Inspection Implementation Schedule

Paragraph 9 Project	Project	Description	CD Milestone Dates		
			Advertise Project	Inspection Completion	Condition and Criticality Evaluation
3	Manhole Inspection	Locating, Raising, Cleaning and Manhole Inspection	5/1/2013	10/1/2014	4/1/2015
4	Sewer Inspection	Cleaning and CCTV Inspection	5/1/2013	10/1/2014	4/1/2015

Hydraulic Improvements:

The schedule provided in Table 7.3.4 represents a reasonable duration for the City to select an engineering consultant to complete the required design documents, advertise the project, select a contractor, implement the required hydraulic improvements and evaluate the effectiveness of the repairs.

Table 7.3.4
Dundalk Sewershed Study and Plan: Sewershed Recommendations
Hydraulic Improvement Schedule

Paragraph 9 Project	Project	Description	CD Milestone Dates		
			Advertise Project	Construction Completion	Evaluation Phase Completion
5	DU06 I/I Removal	CIPP all pipes and rehabilitate all manholes upstream of manhole S71W__001MH (between Chandlery St. and Tributary St.)	1/1/2013	8/1/2014	8/1/2015
6	DU07 I/I Removal	CIPP all pipes and rehabilitate all manholes upstream of manhole S69M__006MH (On Dundalk Ave.)	1/1/2013	10/1/2014	10/1/2015

7.4 Estimating Costs of the Proposed Improvement Projects

To characterize expected costs for the collection system improvements necessary in the Dundalk Sewershed, the City completed a review of information compiled from prior City projects for various types of repairs, rehabilitation and replacement of manholes and sanitary sewers. In addition, the city collected costs from Means' and a national study of unit costs for a wide variety of repair/replacement options in various locations throughout the United States. Once compiled, the information was reviewed, compared and normalized for use by Sewershed consultants in preparing reasonable estimates for the City's sewershed improvements.

The prices utilized in estimating these costs represent average unit costs that were derived from the sources previously mentioned. The City noted however, that there were some significant variations when comparing the unit costs developed by contractors bidding on the same project, and when comparing these documented unit costs with other similar types of repair techniques employed on different projects. Such unit cost variability reflects both the site specific nature of each project as well as the normal variability typically associated with varying markets, project time constraints and other construction related considerations. While it is understood that site specific attributes will have an impact on final costs for a given rehabilitation/repair/replacement effort, it is the City's intent to ensure that all of the sewersheds use the same baseline cost assumptions for consistency and planning purposes. These fully-loaded costs are an attempt to capture all the relevant costs associated with a construction project such as mobilization, bypass pumping, site/paving restoration, and repair of other utilities, which can significantly add to the cost, but are typically required to complete the overall project.

7.4.1 Estimated Improvement Budget

The following sections outline the proposed costs, using the fully-loaded cost data provided by the City, required to implement the First and Second Priority collection system improvements, hydraulic improvements, and inspection of remaining manholes and sewers. The combined total costs associated with completing inspection of remaining manholes and sewers and completing the First and Second Priority manhole repairs, sewer system repairs, and the hydraulic improvements to the conveyance system in the Dundalk Sewershed are estimated to be approximately $7,330,000. All estimated costs are in 2008 dollars. Since the hydraulic improvements is scheduled to begin before the First and Second priority manholes and sewer improvements, the First and Second priority manholes and sewers that are also recommended for hydraulic improvements, have only been accounted for in the hydraulic improvement budget, so as not to duplicate cost.

Estimated Manhole Rehabilitation Budget

Table 7.4.1.1 contains the estimated costs (in 2008 dollars) required to rehabilitate all First and Second Priority sanitary sewer manholes identified in the Dundalk Sewershed collection system. The quantities in this table have been reduced to account for those manholes that will be rehabilitated in the hydraulic improvements. The combined total costs associated with completing the First and Second Priority manhole repairs in the Dundalk Sewershed are estimated to be approximately $79,200.

Table 7.4.1.1				
Dundalk Sewershed Plan: Recommendations				
Estimated Manhole Rehabilitation Improvement Budget				
First Priority Manholes				
Item	Method	Unit Cost	Quantity	Cost
Manhole	Rehabilitation/Replacement	$3,719	3	$11,157
Design, Const. Mngt./Insp., Etc. (42%):				$4,686
Total:				$15,843
Second Priority Manholes				
Item	Method	Unit Cost	Quantity	Cost
Manhole	Rehabilitation/Replacement	$3,719	12	$44,628
Design, Const. Mngt./Insp., Etc. (42%):				$18,744
Total:				$63,372
Total Estimated First and Second Priority Manholes:				**$79,215**

Estimated Sanitary Sewer Rehabilitation Budget:

Table 7.4.1.2A contains the estimated costs (in 2008 dollars) required to rehabilitate all First Priority sanitary sewers identified in the Dundalk collection system. Table 7.4.1.2B documents the estimated costs required to rehabilitate all Second Priority sanitary sewers identified in the Dundalk collection system. Table 7.4.1.2C summarizes the estimated costs required to rehabilitate all First and Second Priority sanitary sewers identified in the Dundalk Sewershed collection system. The combined total costs associated with completing the First and Second Priority sewer (pipeline) system repairs in the Dundalk Sewershed is estimated to be approximately $6,420,000.

Table 7.4.1.2A

Dundalk Sewershed Plan: Recommendations

First Priority Estimated Sanitary Sewer Rehabilitation Improvement Budget

Sewer Size	Unit Cost		Quantity (LF)		Cost
CIPP Lining					
Sewer Size	Unit Cost		Quantity (LF)		Cost
8" Sewer Lining:	$45		2,413		$108,585
8+" - 12" Sewer Lining:	$64		1,908		$122,112
12+" - 18" Sewer Lining:	$87		1,239		$107,793
18+" - 24" Sewer Lining:	$124		1,901		$235,724
24+" - 30" Sewer Lining:	$169		3,499		$591,331
30+" - 36" Sewer Lining:	$186		1,086		$201,996
36+" - 42" Sewer Lining:	$330		3,146		$1,038,180
48+" - 54" Sewer Lining:	$495		238		$117,810
CIPP Lining Subtotal:			15,430		$2,523,531
Estimated Design, Const. Mngt./Insp., Etc. (42%):					$1,059,883
Total First Priority CIPP Lining:					$3,583,414
Point Repairs (Assume 10' Repair)					
Sewer Size	Unit Cost		Quantity (LF)		Cost
24+" - 30" Point Repair:	$841		40		$33,640
30+" - 36" Point Repair:	$988		10		$9,880
Point Repairs Subtotal:			50		$43,520
Estimated Design, Const. Mngt./Insp., Etc. (42%):					$18,278
Total First Priority Point Repairs:					$61,798
Point Repair & CIPP Lining					
Sewer Size	Unit Cost		Quantity (LF)		Cost
	Point Repair	CIPP	Point Repair	CIPP	
8" Point Repair/CIPP:	$378	$45	10	304	$17,460
8+" - 12" Point Repair/CIPP:	$378	$64	30	18	$12,492
Point/CIPP Repairs Subtotal:			40	322	$29,952
Estimated Design, Const. Mngt./Insp., Etc. (42%):					$12,580
Total First Priority Point/CIPP Repairs:					$42,532
Replacement					
Sewer Size	Unit Cost		Quantity (LF)		Cost
8" Replacement:	$270		307		$82,890
42+" - 48" Replacement:	$1,710		871		$1,489,410
Replacement Repairs Subtotal:			1,178		$1,572,300
Estimated Design, Const. Mngt./Insp., Etc. (42%):					$660,366
Total First Priority Replacement Repairs:					$2,232,666
Total Estimated First Priority Sewers:					**$5,920,410**

Table 7.4.1.2B
Dundalk Sewershed Plan: Recommendations
Second Priority Estimated Sanitary Sewer Rehabilitation Improvement Budget

Sewer Size	Unit Cost		Quantity (LF)		Cost
CIPP Lining					
Sewer Size	Unit Cost		Quantity (LF)		Cost
8" Sewer Lining:	$45		657		$29,565
12+" - 18" Sewer Lining:	$87		1,307		$113,709
18+" - 24" Sewer Lining:	$124		253		$31,372
CIPP Lining Subtotal:			2,217		$174,646
Estimated Design, Const. Mngt./Insp., Etc. (42%):					$73,351
Total Second Priority CIPP Lining:					$247,997
Point Repairs					
Sewer Size	Unit Cost		Quantity (LF)		Cost
8" Point Repair:	$378		0		$0
Point Repairs Subtotal:			0		$0
Estimated Design, Const. Mngt./Insp., Etc. (42%):					$0
Total Second Priority Point Repairs:					$0
Point Repair & CIPP Lining					
Sewer Size	Unit Cost		Quantity (LF)		Cost
	Point Repair	CIPP	Point Repair	CIPP	
8" Point Repair/CIPP:	$378	$45	60	240	$33,480
12+" - 18" Point Repair/CIPP:	$378	$87	210	586	$130,362
30+" - 36" Point Repair/CIPP:	$988	$186	10	19	$13,414
Point/CIPP Repairs Subtotal:			280	845	$177,256
Estimated Design, Const. Mngt./Insp., Etc. (42%):					$74,448
Total Second Priority Point/CIPP Repairs:					$251,704
Replacement					
Sewer Size	Unit Cost		Quantity (LF)		Cost
8" Replacement:	$270		0		$0
Replacement Repairs Subtotal:			0		$0
Estimated Design, Const. Mngt./Insp., Etc. (42%):					$0
Total Second Priority Replacement Repairs:					$0
Total Estimated Second Priority Sewers:					**$499,701**

Table 7.4.1.2C
Dundalk Sewershed Plan: Recommendations
Sanitary Sewer Improvement Budget Summary

Priority	CIPP Lining Repair Cost	Point Repair Cost	Point/CIPP Repair Cost	Replacement	Total
First	$3,583,414	$61,798	$42,532	$2,232,666	$5,920,410
Second	$247,997	$0	$251,704	$0	$499,701
Total	**$3,831,411**	**$61,798**	**$294,236**	**$2,232,666**	**$6,420,111**

Estimated Inspection Budget for Manholes and Sewers:

Table 7.4.1.3 contains the estimated costs required to complete inspection of the remaining manholes and sewers (refer to Section 7.2.2 for details) in the Dundalk Sewershed. The total cost is estimated to be approximately $187,000 in 2008 dollars.

Table 7.4.1.3
Dundalk Sewershed Plan: Recommendations
Estimated Manhole and Sewer Inspection Budget

Manhole Inspection					
Item	Unit Cost			Quantity (Each)	Cost
Manhole (CNO)[1]	Open: $230	Inspect: $125		4	$1,420
Manhole (RCL)[2]	Clean: $440	Inspect: $125		4	$2,260
Manhole (BUR)[3]	Expose: $400	Raise: $700	Inspect: $125	41	$50,225
Manhole (TRF)[4]	$125			2	$250
Manhole (ESM)[5]	$125			4	$500
				Sub-total:	$54,655
				Design, Const. Mngt./Insp., Etc. (42%):	$22,955
				Total:	$77,610
Sewer CCTV					
Item	Unit Cost			Quantity (LF)	Cost
8" - 12"	$5			5,965	$29,825
12+" - 18"	$5			1,510	$7,550
18+" - 36"	$5			5,255	$26,275
36+" - 66"	$5			2,670	$13,350
				Sub-total:	$77,000
				Design, Const. Mngt./Insp., Etc. (42%):	$32,340
				Total:	$109,340
				Total Inspection Cost for Manholes and Sewers:	**$186,950**

[1] CNO: manhole bolted or with concrete cover; [2] RCL: manhole requires cleaning; [3] BUR: manhole buried; [4] TRF: manhole at traffic site; [5] ESM: manhole with easement access issue.

Estimated Hydraulic Improvements Budget:

Table 7.4.1.4 contains the estimated costs required to complete the hydraulic improvements based on a 2- Year storm event for basins DU06 and DU07 in the Dundalk Sewershed. The combined total cost associated with completing the hydraulic improvements in 2008 dollars is estimated to be approximately $642,000.

As stated previously, all First and Second priority manholes and sewer pipes in DU06 and DU07 that have also been recommended for hydraulic improvements, have been included in the hydraulic improvement budget (Table 7.4.1.4), and not duplicated in the First and Second priority manholes and Sewer improvement budget.

Table 7.4.1.4
Dundalk Sewershed Plan: Recommendations
Estimated Hydraulic Improvement Budget

Item	Rehabilitation Method	Unit Cost	Quantity (LF)	Cost
DU06				
8" Pipe	CIPP	$45	1,844	$82,980
10" Pipe	CIPP	$64	319	$20,416
12" Pipe	CIPP	$64	125	$8,000
Manhole (each)	Rehab/Replacement	$3,719	15	$55,785
			Subtotal:	$167,181
Estimated Eng. Design, Const. Mgt./Insp., Admin., Post Eng. Services & Cont. (42%):				$70,216
			Total:	$237,397
DU07				
8" Pipe	CIPP	$45	4,841	$217,845
Manhole (each)	Rehab/Replacement	$3,719	18	$66,942
			Subtotal:	$284,787
Estimated Eng. Design, Const. Mgt./Insp., Admin., Post Eng. Services & Cont. (42%):				$119,611
			Total:	$404,398
Total Estimated Hydraulic Improvement Costs:				**$641,795**

7.5 Re-inspection Program

As specified in the CD, the Dundalk Sewershed collection system needs to be re-inspected by January 1, 2016. The following sections outline the requirements of the re-inspection program and provide a general schedule to complete this work.

7.5.1 Re-Inspection Prioritization Scheme

The City's condition and criticality protocol provides a framework for a continuous rehabilitation strategy of all collection system components based on both criticality (consequence of failure) and condition (probability of failure). Assets whose failure can have large impacts on the community and the environment and whose condition is the poorest will receive a higher criticality and condition rating and will receive attention in a more timely manner. Assets that receive a lower criticality and condition rating will receive some level of continued monitoring as recommended herein but no immediate action or rehabilitation. Refer to **Section 7.1** Decision Making Criteria for details. The following sections detail the requirements of future inspection programs.

7.5.2 CCTV and Manhole Inspections

The implementation schedule provided includes provisions for the re-inspection of collection system components in the Dundalk Sewershed by January 1, 2016. The proposed re-inspection schedule includes provisions for, but is not necessarily limited to, a prioritization scheme for further inspection of collection system components based on the following criteria:

1) Prior identification of system defects, prior NASSCO PACP or MACP rating codes, grease blockages, root intrusion or system complaint data.
2) Prior criticality and condition ratings.
3) Expected life cycle of system components.
4) Estimated rate of existing or potential inflow and/or infiltration.
5) Scheduled rehabilitation or other corrective action of a system component; and the predetermined re-inspection frequency of a collection system component.

Current sewershed studies are scheduled to be completed between January 2009 and July 2010. Following these studies, the City intends to implement a continuous CCTV and manhole inspection program aimed at re-inspecting all gravity sewers 8-inch in diameter and larger, and all force mains, pump stations, manholes and other sewer structures by January 1, 2016. The planned re-inspection activities will be prioritized based on the condition and criticality factors determined during this project.

The implementation schedule for re-inspection of these sewershed system components is outlined in Table 7.5.2.1.

Table 7.5.2.1
Dundalk Sewershed Study and Plan: Sewershed Recommendations
Sewershed Re-Inspection Implementation Schedule

Task	Duration (Yrs.)	Start Date	End Date	2011	2012	2013	2014	2015	2016
Manhole Inspections	2 1/2	1/1/2013	6/30/2015						January 1, 2016
Analysis and Report	1	7/1/2014	12/1/2015						
Pump Station Inspection	1/2	7/1/2014	12/31/2014						
Analysis and Report	1/2	1/1/2015	6/30/2015						
Force Main Inspections	1/2	7/1/2014	12/31/2014						
Analysis and Report	1/2	1/1/2015	7/1/2015						
Sewer Inspections	2 1/2	1/1/2013	6/30/2015						
Analysis and Report	1	1/1/2014	12/1/2015						

In accordance with BaSES and based on the condition of the assets observed during this study, the following program is recommended:

- Manholes and sewers that received higher condition and criticality rating scores were recommended for inclusion on the First and Second Priority corrective action plan.
- Once rehabilitated, these manholes and sewers should be placed on a “Low Priority” inspection program with regular inspections occurring once every 5 to 10 years.
- The manholes and sewers that received condition ratings of 3 were classified as requiring “Frequent Assessment” under the condition and criticality rating system should be inspected on regular 2-3 year inspection intervals to insure the continuity of the collection system.
- Manholes and sewer segments that are currently in serviceable condition but received higher criticality ratings were identified as requiring “Regular Monitoring” and should be inspected every 3-5 years. Based on the results of those inspections, any manholes and/or sewers that have continued to deteriorate to a point that requires repair should be repaired on an as-needed basis to address specific problems or deficiencies that have occurred.

7.6 Future Data Collection and Evaluation Services

As required by the CD, under Paragraph 9-C-xii, the City will be required to implement several continuous data collection programs in order to assess the effectiveness of the rehabilitation programs and other O&M enhancement efforts within the sewershed. These programs will be comprehensive, system-wide initiatives that will include a long-term flow monitoring plan, a sewer cleaning program, CCTV and manhole inspection programs and root control and grease control programs. These are discussed in more detail in the following sections.

7.6.1 Long-Term Flow Monitoring Plan

In 2006 the City of Baltimore implemented a comprehensive flow monitoring program for the purpose of evaluating the severity of infiltration and inflow and for calibration of the hydraulic model. This comprehensive program consisted of a network of about 350 flow meters, 20 rain gauges, 33 groundwater monitoring stations and extended for a period of one year from May 2006 through May 2007. In May 2007, the network was reduced to about 100 flow meters that were placed at key points and junctions in the collection system for the purpose of long term assessment and continuous calibration of the hydraulic model. In the Dundalk sewershed, there are five (5) long term flow monitors, four (4) of which are located on the City-County boundary line to monitor the wastewater contribution from Baltimore County. All 20 rain gauges remained in operation after the one year period. The City plans to continue monitoring the flows in order to assess the effectiveness of the on-going and future rehabilitation and O&M enhancement programs.

7.6.2 Sewer Cleaning Program

The effectiveness of a sewer conveyance system is largely dependent on its ability to convey the flows generated within the sewer basin without surcharging the system to a point where overflows occur. As part of the sewer inspection program completed for this study, all sewers that were inspected were also cleaned. The intent of the cleaning was to clean the sewer so the inspections could identify defects that otherwise would not be visible during the inspection and to remove debris and restore the sewer to at least 95% of its original carrying capacity. When significant restrictions such as roots or other debris were encountered, heavy cleaning was utilized to restore the capacity of the sewers and allow for internal inspection. Heavy cleaning involved root cutting, grease removal and/or additional passes of the hydro-cleaning equipment to remove heavy accumulations of sediment and debris. Debris were removed from the sewers and disposed of at an approved disposal site. When significant blockages were encountered that could not be addressed by cleaning operations, they were reported to the City and the City promptly coordinated with the wastewater maintenance division or their on-call contractor to resolve the deficiency.

Based on the cleaning work completed during this project and observations from the inspection work completed, it is recommended that sewers which contain heavy accumulations of grease, debris and/or roots, large sewer interceptors, sewer siphons, and sewers with velocities less than 3 feet per second (fps) should be cleaned every 5 years. These cleaning operations should be closely coordinated with the sewer re-inspection program, which needs to be completed by January 1, 2016 and prioritized based on condition and criticality rating factors that were determined during the inspections described in Section 7.1. Under normal operating conditions, the remaining sewers should not require additional cleaning between the 5 to 10 year Low Priority sewer inspection cycles.

7.6.3 CCTV and Manhole Inspection Programs

The City intends to implement a continuous city-wide CCTV and manhole inspection programs following the completion of the sewershed studies, which are scheduled to be completed between January 2009 and July 2010. These programs will be aimed at re-inspecting all gravity sewers 8-inches in diameter and larger, force mains, pump stations, manholes and other sewer structures by January 1, 2016. The planned re-inspection activities will be prioritized based on each segment's condition and criticality ratings that were derived during the sewershed inspections described in Section 7.1 of this report.

Based on the results of the inspections completed during this sewershed study, the re-inspection schedule identified by the CD and the rehabilitation work which has been detailed as part of this plan, it is recommended that all Frequent Assessment assets in the Dundalk Sewershed be re-inspected every 2 to 3 years to reassess their condition and assign appropriate repairs as needed. All First and Second Priority Rehabilitation Projects should be placed under the Frequent Assessment Program upon their completion. All Regular Monitoring Assets should be re-inspected every 3 to 5 years, and all Low Priority assets re-inspected every 5 to 10 years.

7.6.4 Root Control Program

In 2004, the City began monitoring the impacts of root infestation in their collection system by tracking and geocoding customer calls related to root problems in the sewer. In 2006, the City identified an area in the Herring Run Sewershed having severe root intrusion problems (approximately 1,500 acres, 230,000 linear feet of pipe). The City proceeded to implement a root control chemical application pilot project in this area in 2007. This included the treatment of approximately 150 house laterals and service connections. The pilot project yielded promising results; therefore the City expanded the Root Control Program (RCP) into other areas of the collection system with documented root intrusion problems. A recent evaluation of customer calls in 2007 identified two additional areas with severe root infestation as shown in Figure 7.6.4.1. One area is located in the Western Run section of the Jones Falls Sewershed, and the other in the Maidens Choice section of the Gwynns Falls Sewershed. This latest evaluation indicates that root infestation in the Dundalk Sewershed is considered moderate and will receive due priority in the Root Control Program.

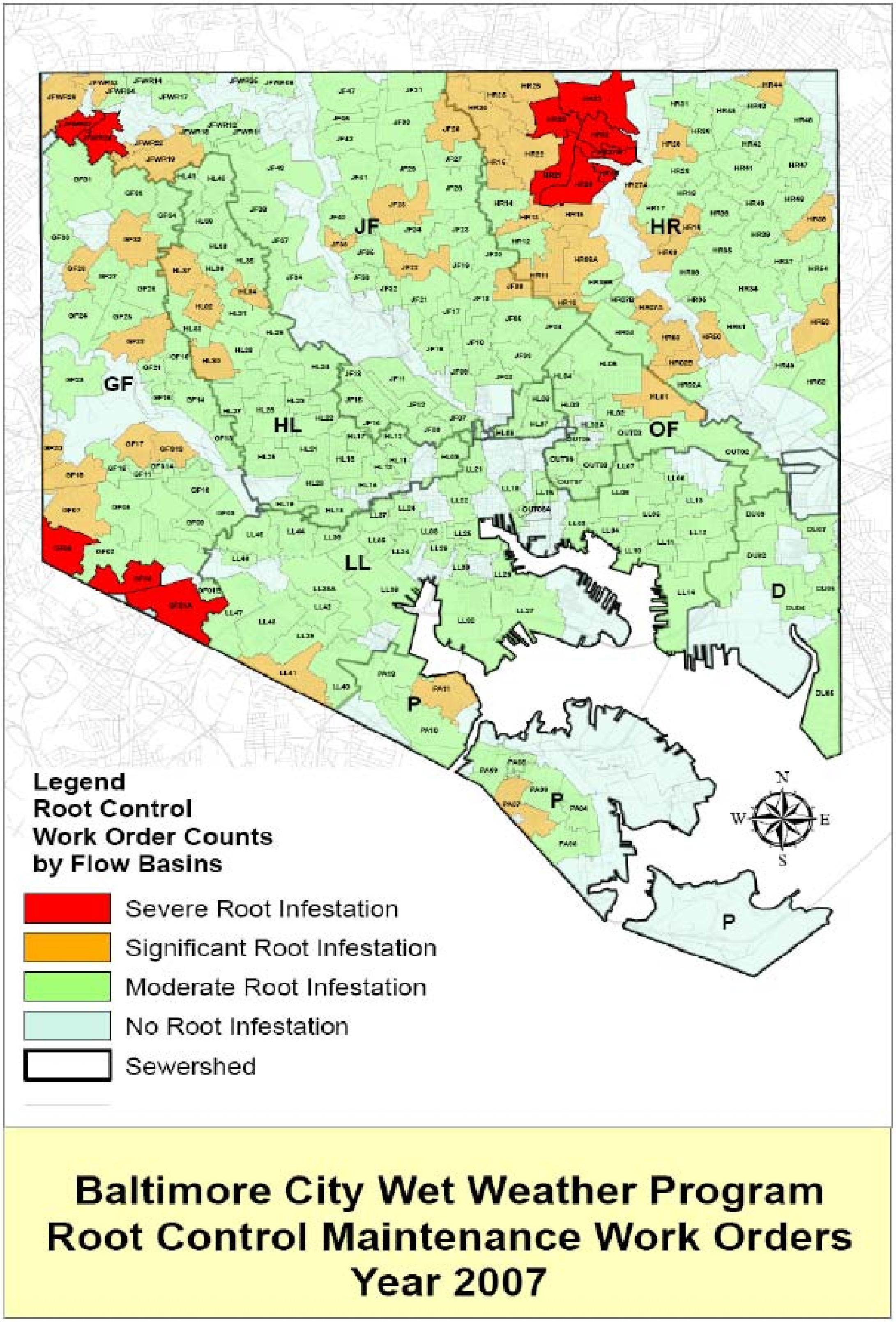


Figure 7.6.4.1 Baltimore City Root Control Work Orders 2007

7.6.5 Fats, Oils, and Grease Control Programs

Similar to root infestation in the sewer system, the City also began assessing the impacts of Fats, Oils and Grease (FOG) in the collection system in 2004. The City geocoded and mapped all customer complaint calls related to FOG and identified five sections of the collection system where severe problems exist. Not surprisingly, these sections serve areas with numerous restaurants and/or food establishments, namely Little Italy, the Johns Hopkins Hospital area, which has many restaurants serving the hospital community, and the upper reaches of the High Level Sewershed, which have numerous restaurants and a major mall with a food court.

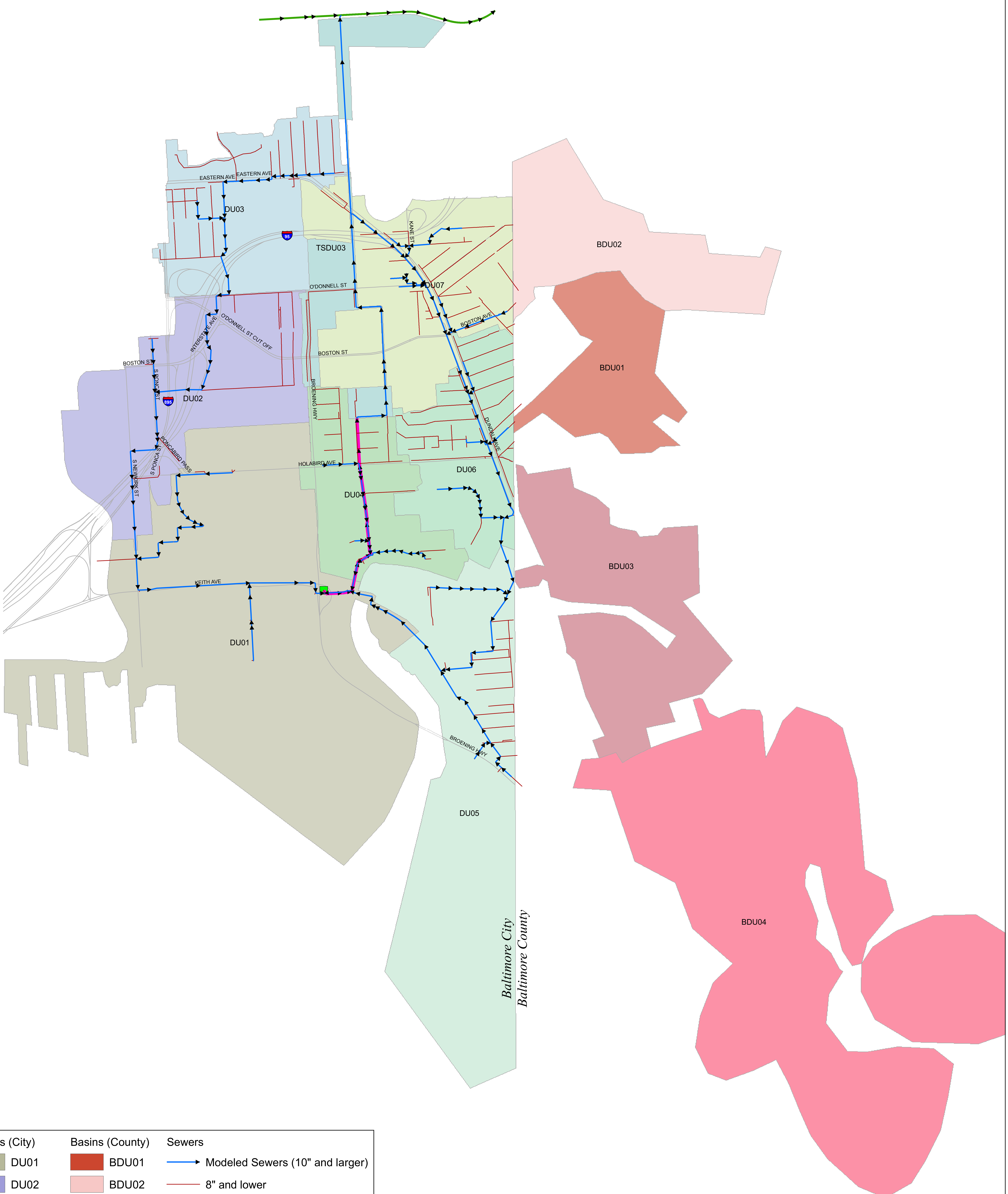
The City proceeded to outfit two of its newest sewer vac-trucks with de-greasing equipment and began treating the targeted areas in 2006. These areas are currently on a regular cleaning schedule and are addressed twice a year for grease. The City will continue to evaluate customer complaint calls and utilize CCTV and manhole inspection data in order to assess and guide future activities of the FOG Program.

7.6.6 Force Main Inspection

The force main inspection was performed using a sensor head that was successfully inserted into the force main through a 30" gate valve chamber just outside of the Dundalk Pump Station. However, the inspection on March 17, 2009 stopped after reaching 1,932 feet due to high pull back pressures on the sensor and cable.

RJN Group, Inc. located another insertion point, a force main chamber near 6200 Beckley Street and coordinated with the Pressure Pipe Inspection Company, the City of Baltimore, and the tapping contractor on the placement of a tap on the force main chamber for the purpose of completing the force main inspection. The inspection resumed on November 30, 2009 and covered a total of approximately 1,920 feet of the force main.

The inspections on March 17 and November 30, 2009 identified no leaks or gas pockets in the inspected force main. There were, however, 45 pressure transients, or "water hammers", detected over the monitoring period ranging from 0.3 psi to 55.4 psi. More detail on the findings of the force main inspection is reported in Section 4.8. It is recommended that experts should be consulted to determine if the pressure transients have negative effects on the structural integrity of the force main.



Basins (City)
- DU01
- DU02
- DU03
- DU04
- DU05
- DU06
- DU07
- TSDU03

Basins (County)
- BDU01
- BDU02
- BDU03
- BDU04

Sewers
- Modeled Sewers (10" and larger)
- 8" and lower
- Outfall Interceptor
- Force Main

Pump Station

Map 1.5.1

STEPHANIE RAWLINGS-BLAKE
MAYOR

Project 1047 - Dundalk Collection System Evaluation & Sewershed Plan

Major Sewers and Pump Station

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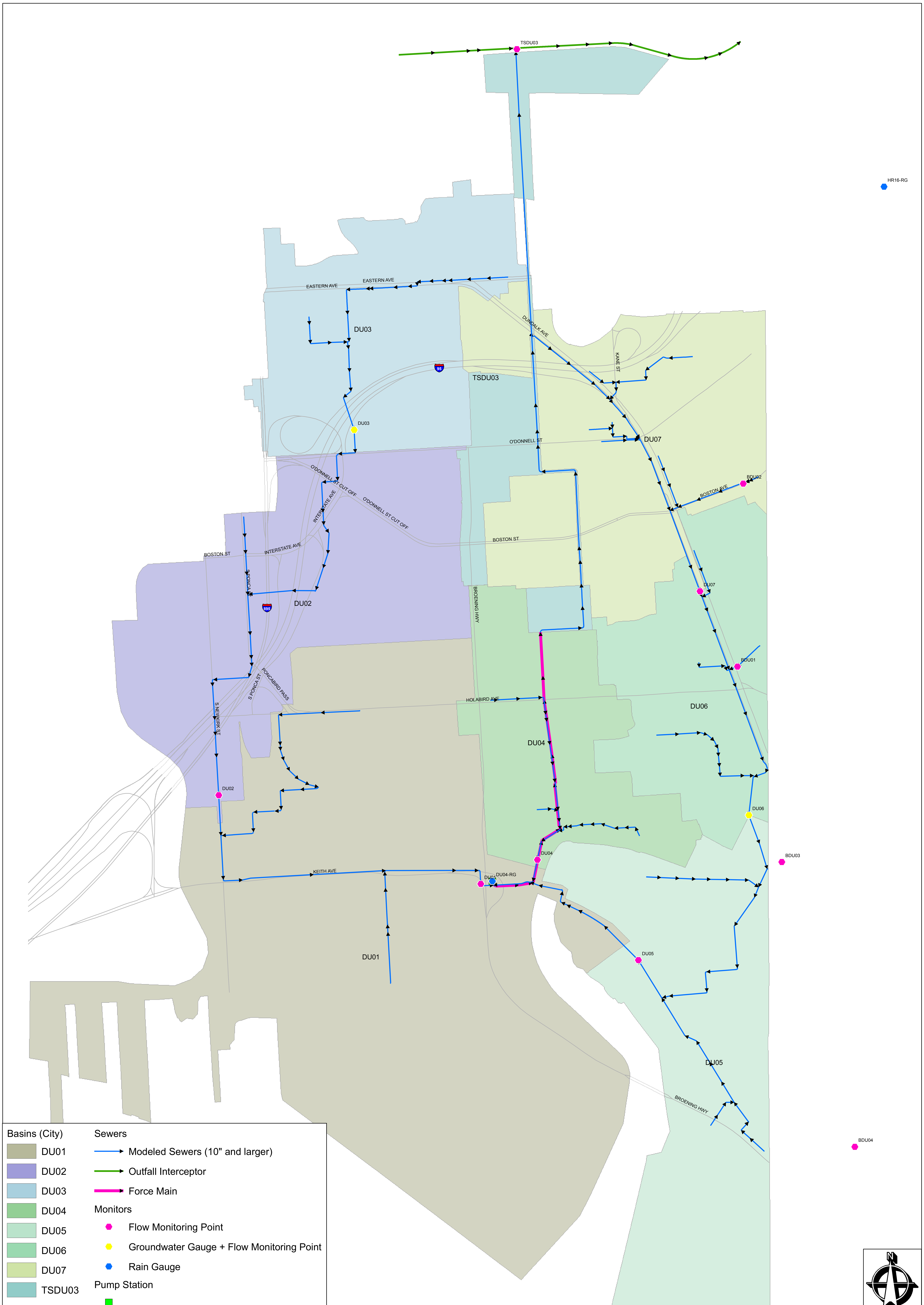
Excellence through Ownership

March 1st, 2010

Scale: 1 inch = 900 feet



Map 3.2.1

CITY OF BALTIMORE

STEPHANIE RAWLINGS-BLAKE
MAYOR

Project 1047 - Dundalk Collection System Evaluation & Sewershed Plan

Dundalk Flow Monitoring and Rain Gauge Network

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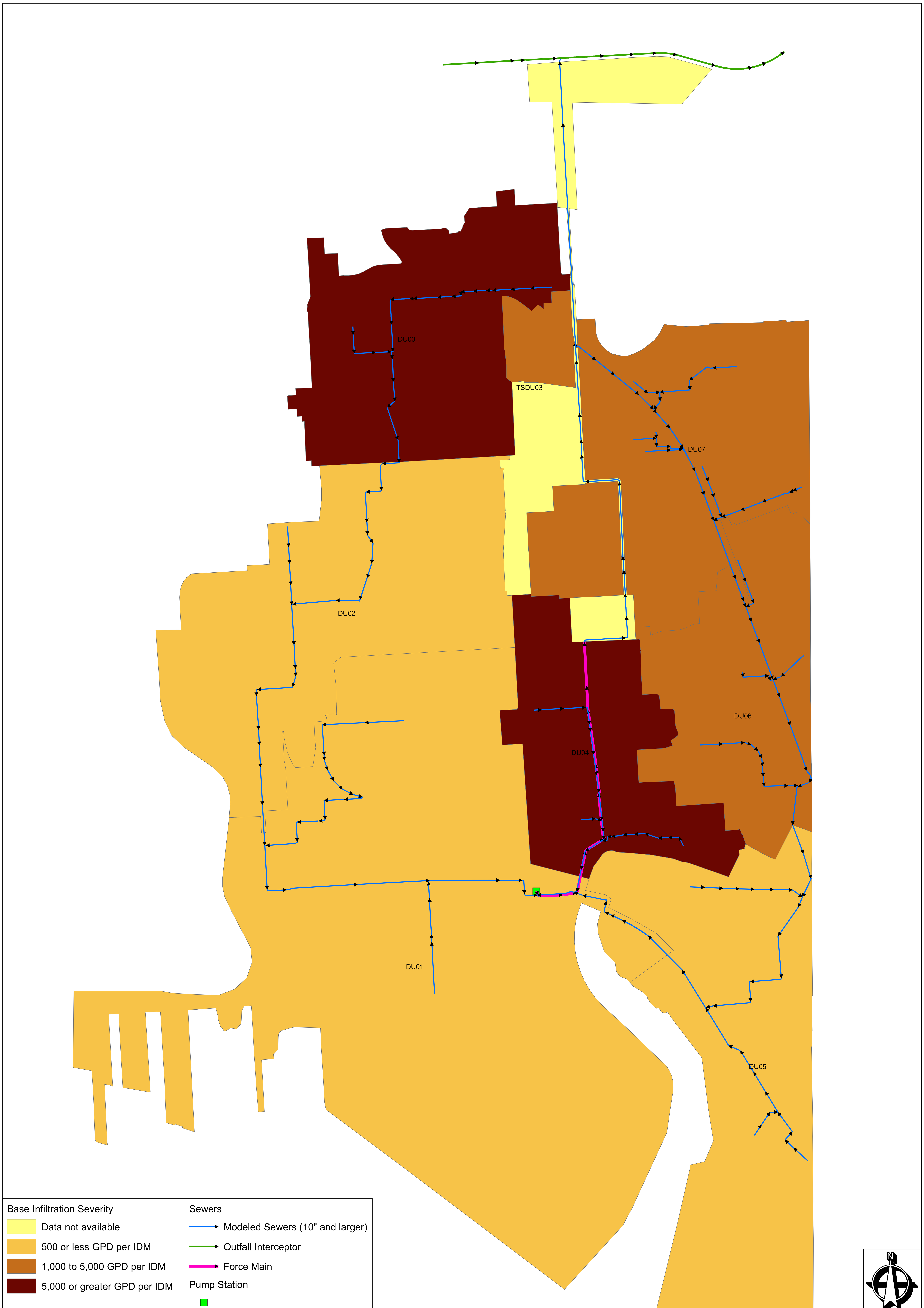
Excellence through Ownership

March 1st, 2010

Scale: 1 inch = 1.25 miles



Map 3.6.1

STEPHANIE RAWLINGS-BLAKE
MAYOR

Project 1047 - Dundalk Collection System Evaluation & Sewershed Plan

Dundalk Base Infiltration Severity Map

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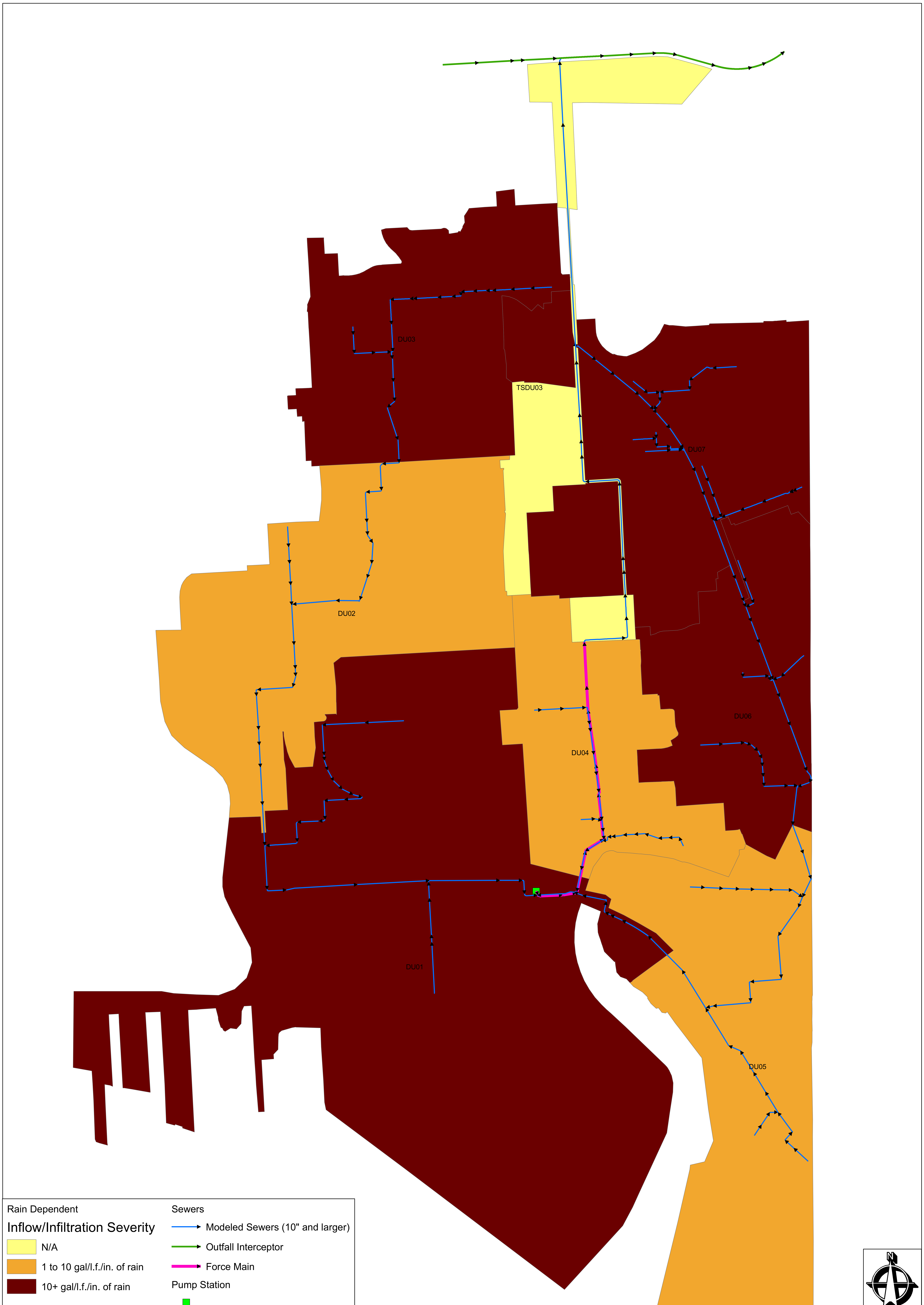
March 1st, 2010

Scale: 1 inch = 1.25 miles



Map 3.7.1

STEPHANIE RAWLINGS-BLAKE
MAYOR

Project 1047 - Dundalk Collection System Evaluation & Sewershed Plan

Dundalk RDII Severity Map

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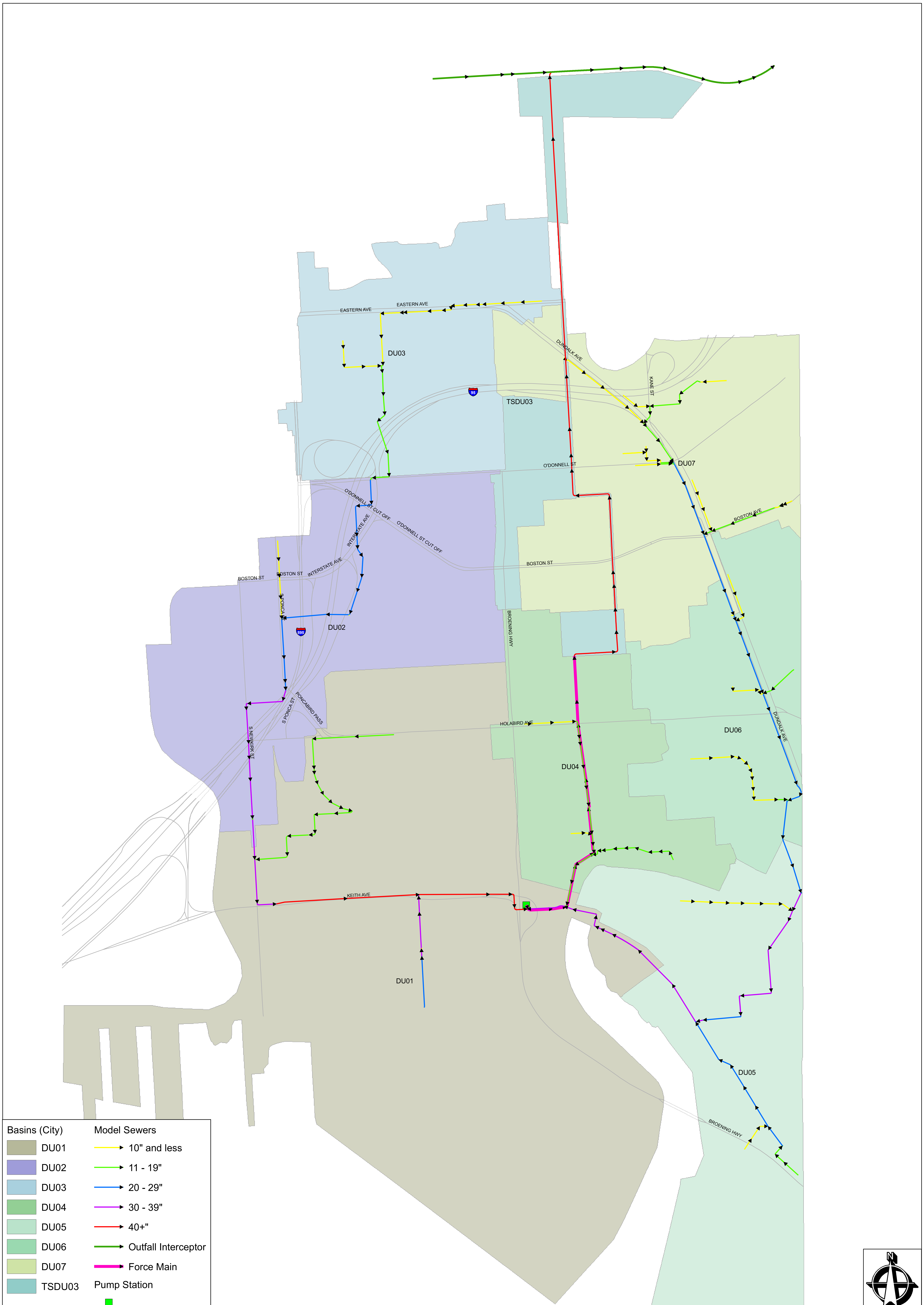
March 1st, 2010

Scale: 1 inch = 1.25 miles



Map 5.1.1

STEPHANIE RAWLINGS-BLAKE
MAYOR

Project 1047 - Dundalk Collection System Evaluation & Sewershed Plan

Dundalk Model Network

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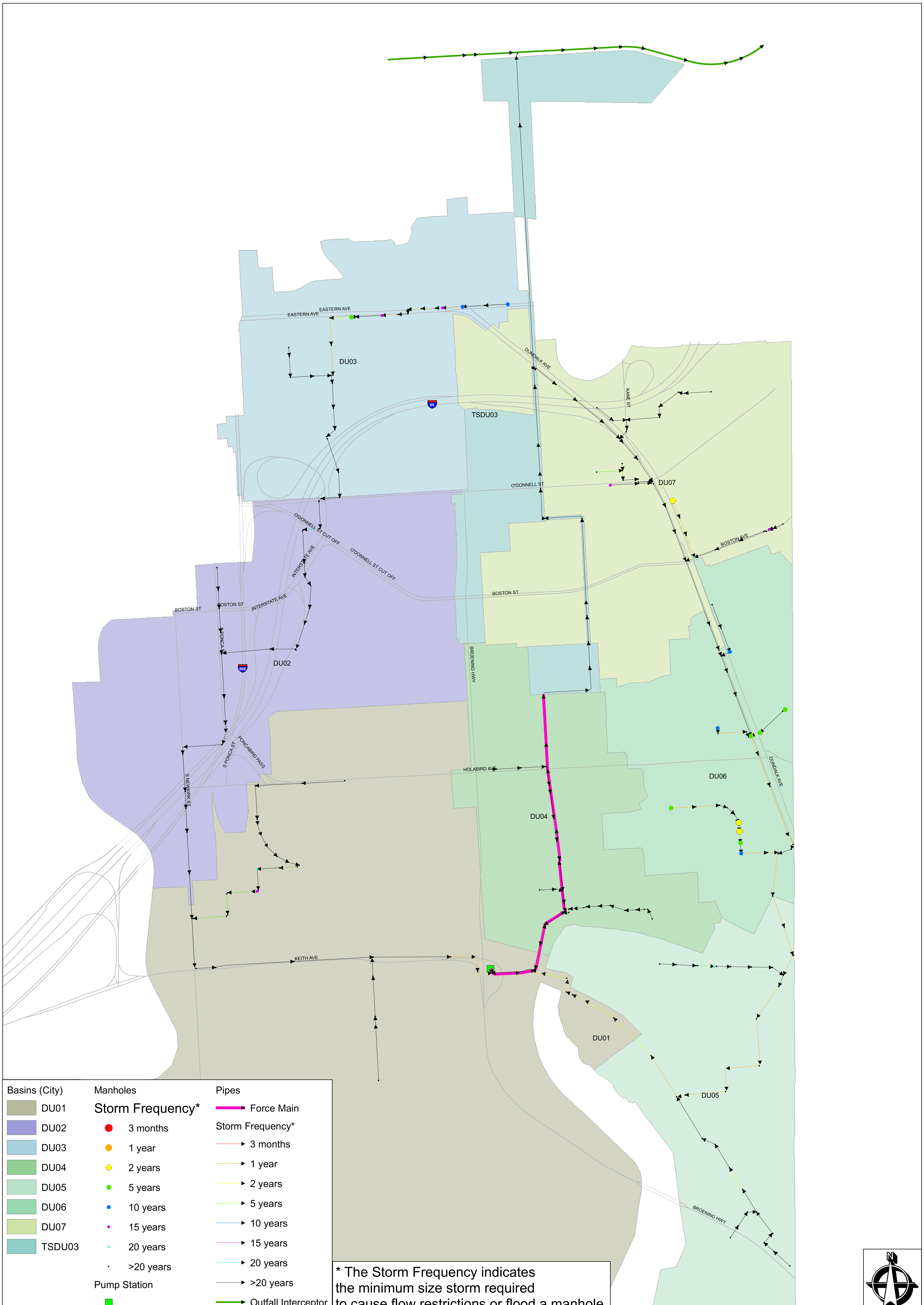
March 1st, 2010

Scale: 1 inch = 1.25 miles



Map 5.3.3A

STEPHANIE RAWLINGS-BLAKE
MAYOR

Project 1047 - Dundalk Collection System Evaluation & Sewershed Plan

Dundalk Storm Simulation Results (All Pumps Online, Baseline Conditions, Year 2007)

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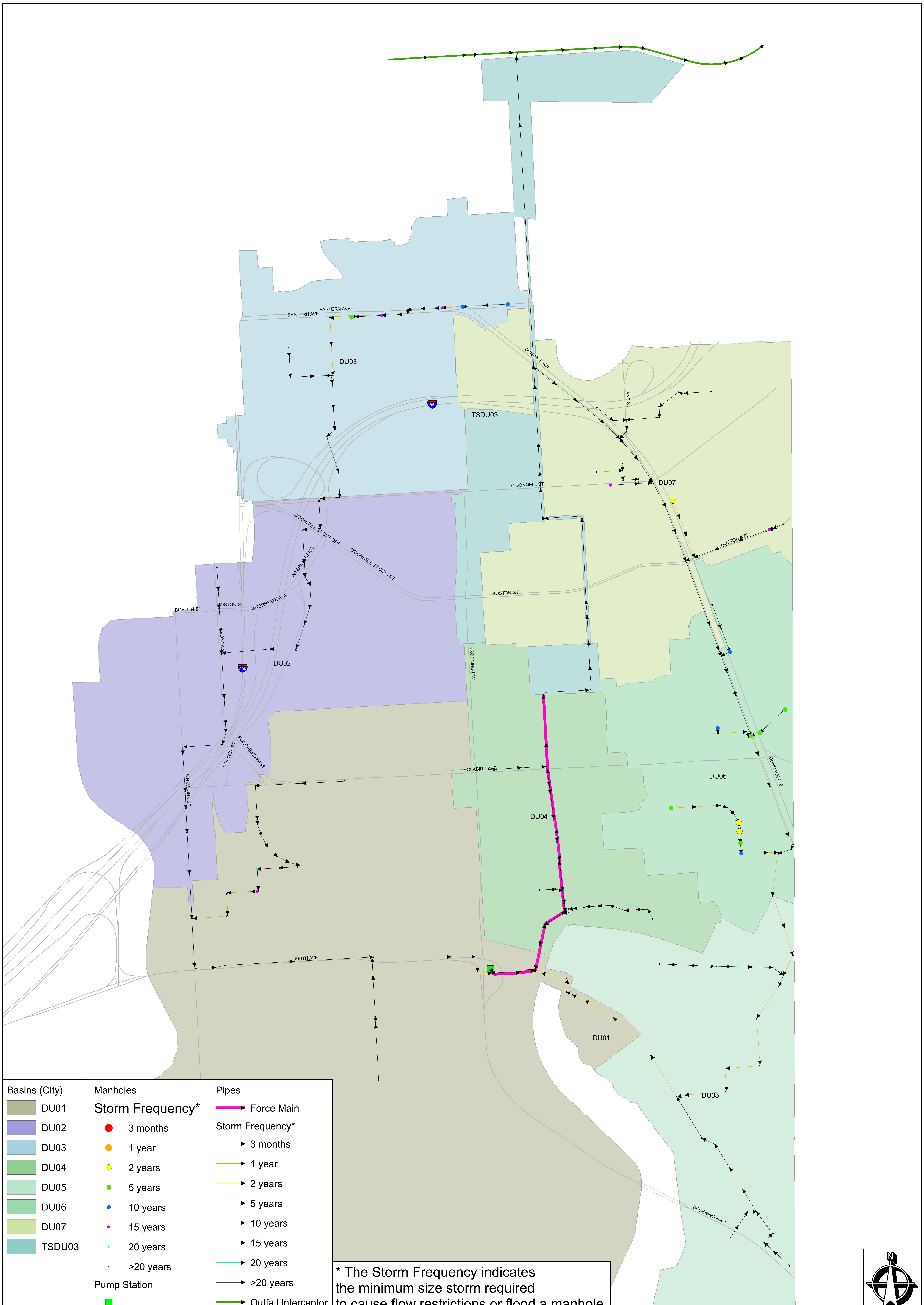
Excellence through Ownership

March 1st, 2010

Scale: 1 inch = 500 feet



Map 5.3.3B

STEPHANIE RAWLINGS-BLAKE
MAYOR

Project 1047 - Dundalk Collection System Evaluation & Sewershed Plan

Dundalk Storm Simulation Results (Backup Pumps Offline, Baseline Conditions, Year 2007)

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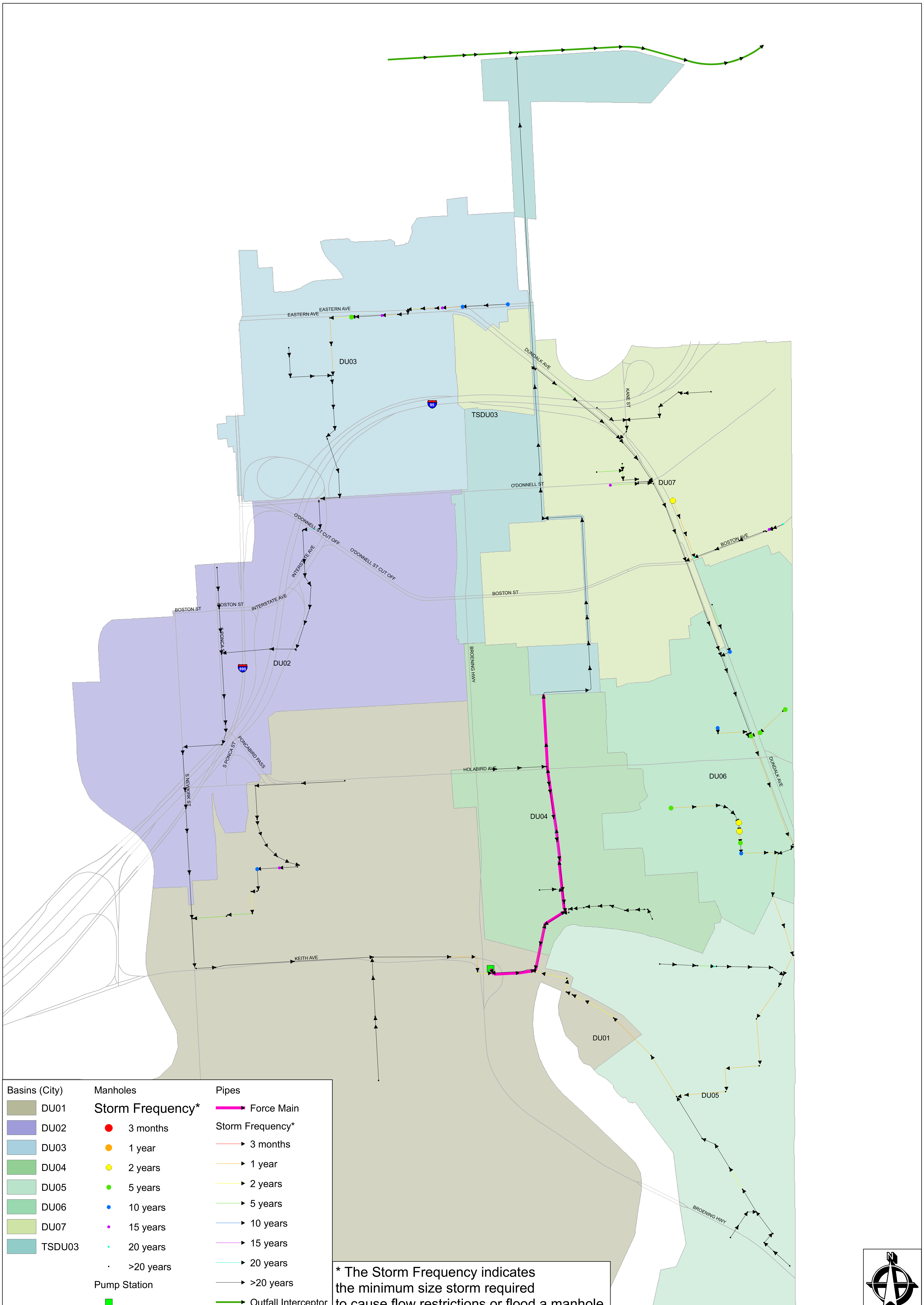
Excellence through Ownership

March 1st, 2010

Scale: 1 inch = 500 feet



Map 5.3.3C

STEPHANIE RAWLINGS-BLAKE
MAYOR

Project 1047 - Dundalk Collection System Evaluation & Sewershed Plan

Dundalk Storm Simulation Results (All Pumps Online, Future Conditions, Year 2025)

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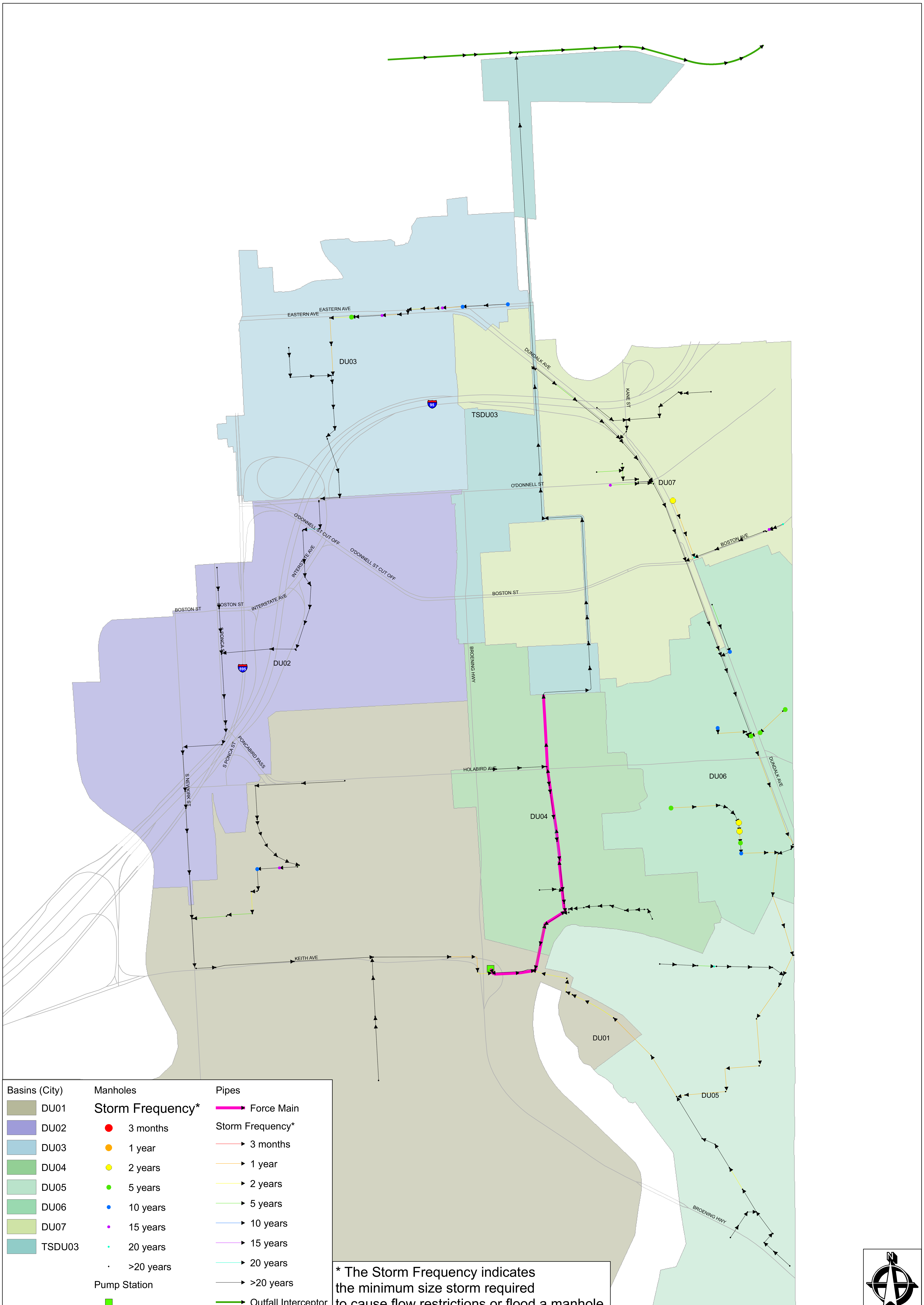
Excellence through Ownership

March 1st, 2010

Scale: 1 inch = 500 feet



Map 5.3.3D

CITY OF BALTIMORE

STEPHANIE RAWLINGS-BLAKE MAYOR

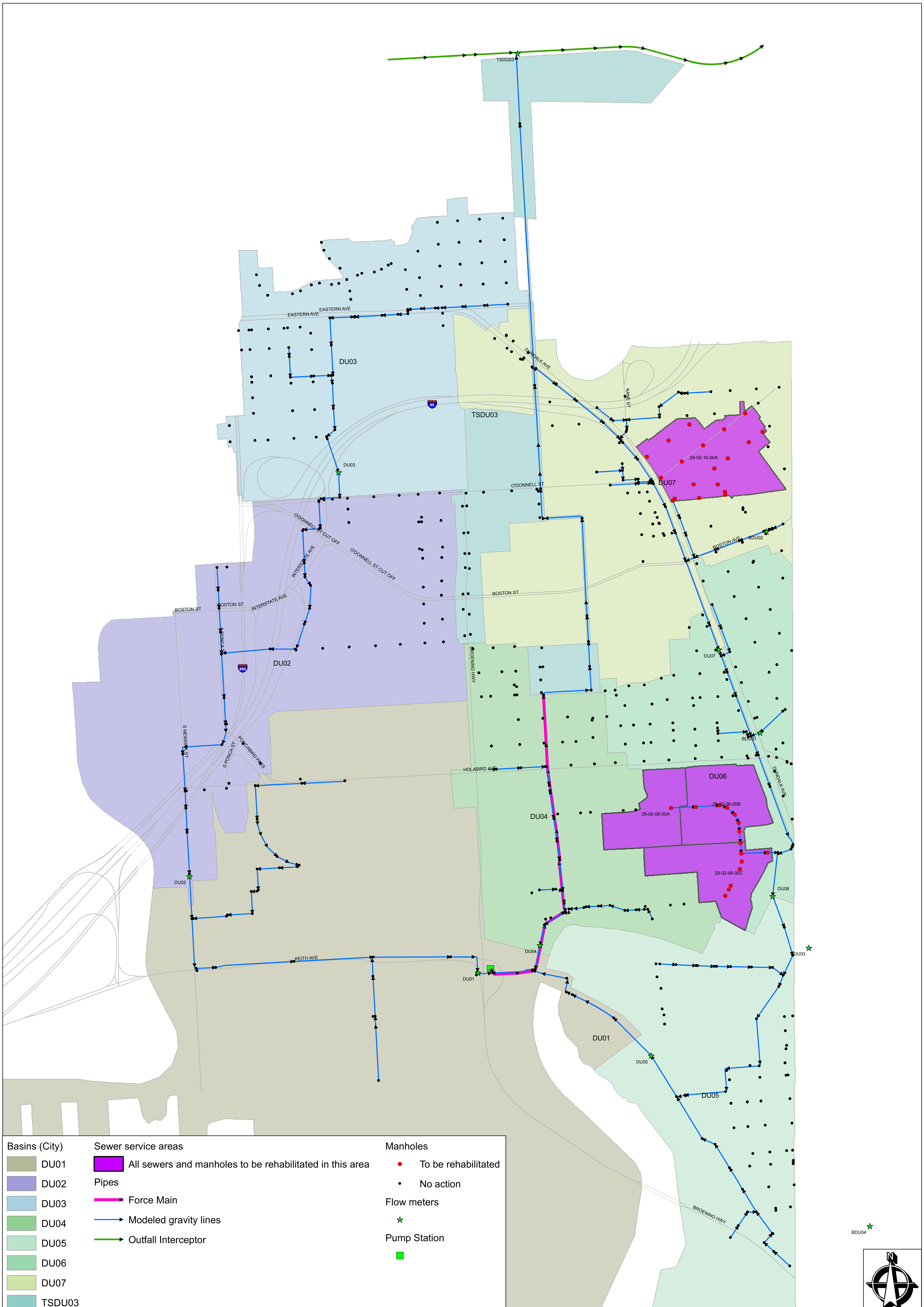
Project 1047 - Dundalk Collection System Evaluation & Sewershed Plan

Dundalk Storm Simulation Results (Backup Pumps Offline, Future Conditions, Year 2025)

rjngroup
Excellence through Ownership

March 1st, 2010

Scale: 1 inch = 500 feet



Map 5.4.1

STEPHANIE RAWLINGS-BLAKE
MAYOR

Project 1047 - Dundalk Collection System Evaluation & Sewershed Plan

Dundalk Alternative Analysis (2-Year Storm)

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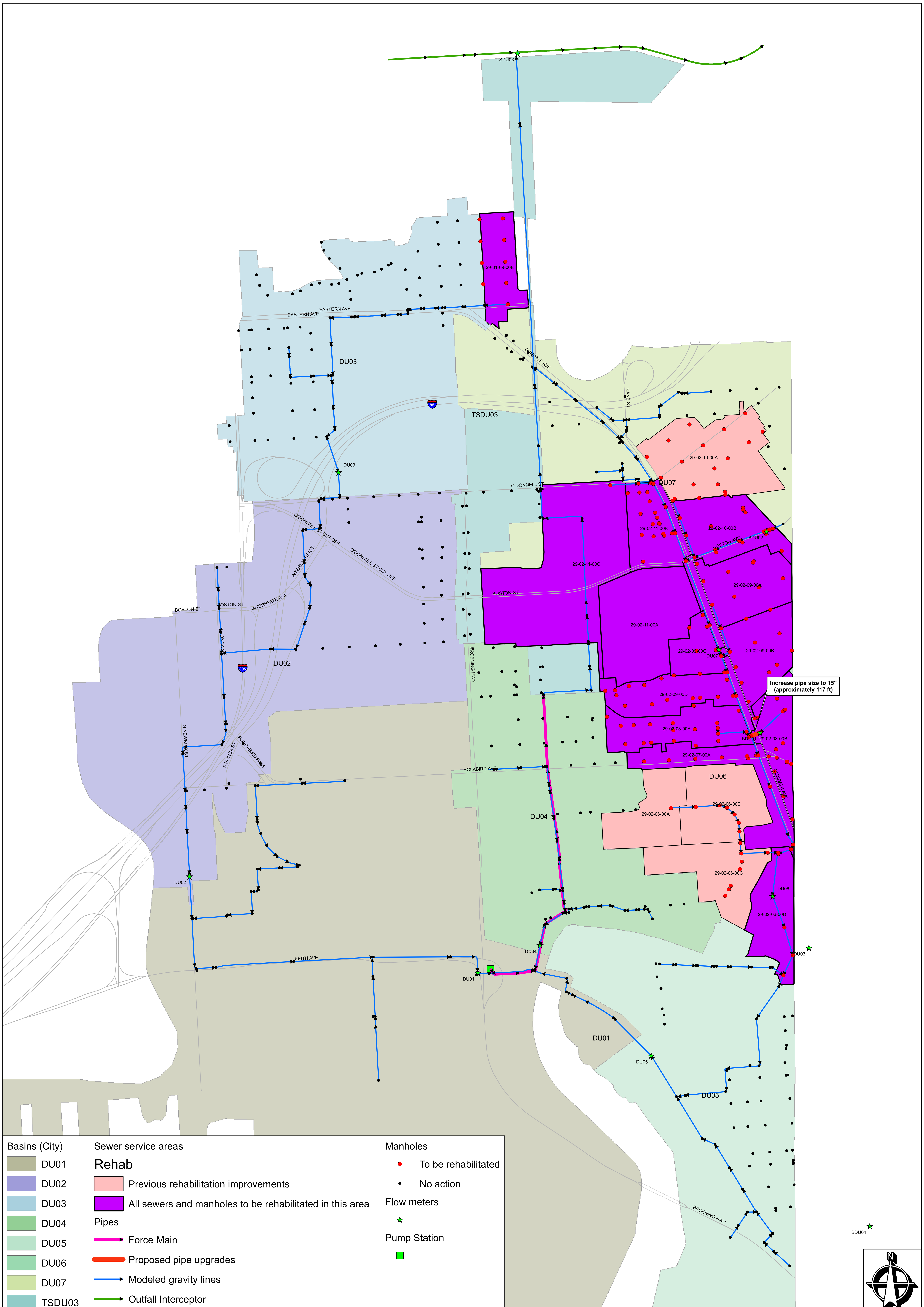
Excellence through Ownership

March 1st, 2010

Scale: 1 inch = 500 feet



Map 5.4.2

CITY OF BALTIMORE

STEPHANIE RAWLINGS-BLAKE
MAYOR

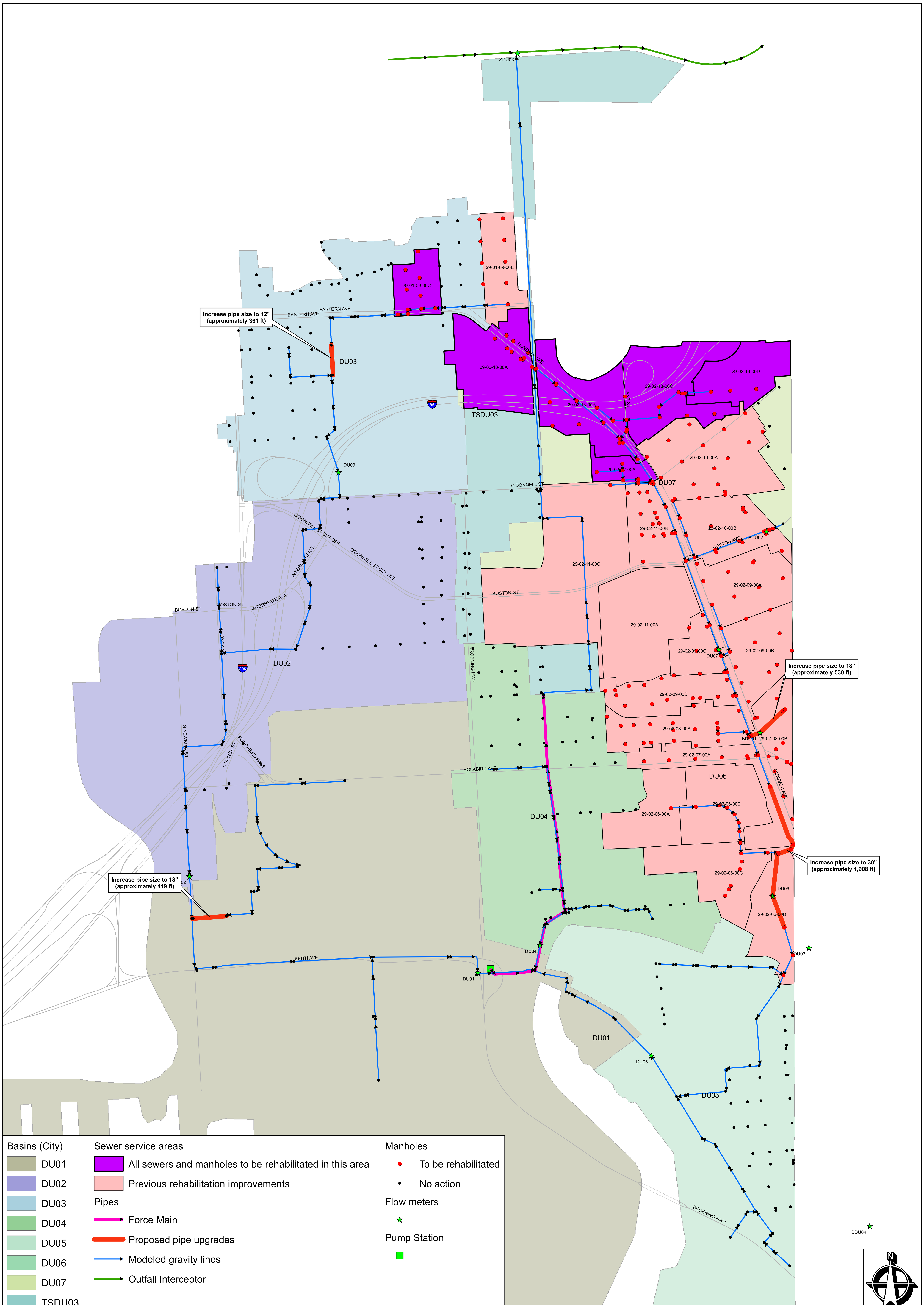
Project 1047 - Dundalk
Collection System Evaluation
& Sewershed Plan

Dundalk Alternative Analysis
(5-Year Storm)

rjngroup
Excellence through Ownership

March 1st, 2010

Scale: 1 inch = 500 feet



Map 5.4.3

CITY OF BALTIMORE

STEPHANIE RAWLINGS-BLAKE
MAYOR

Project 1047 - Dundalk Collection System Evaluation & Sewershed Plan

Dundalk Alternative Analysis (10-Year Storm)

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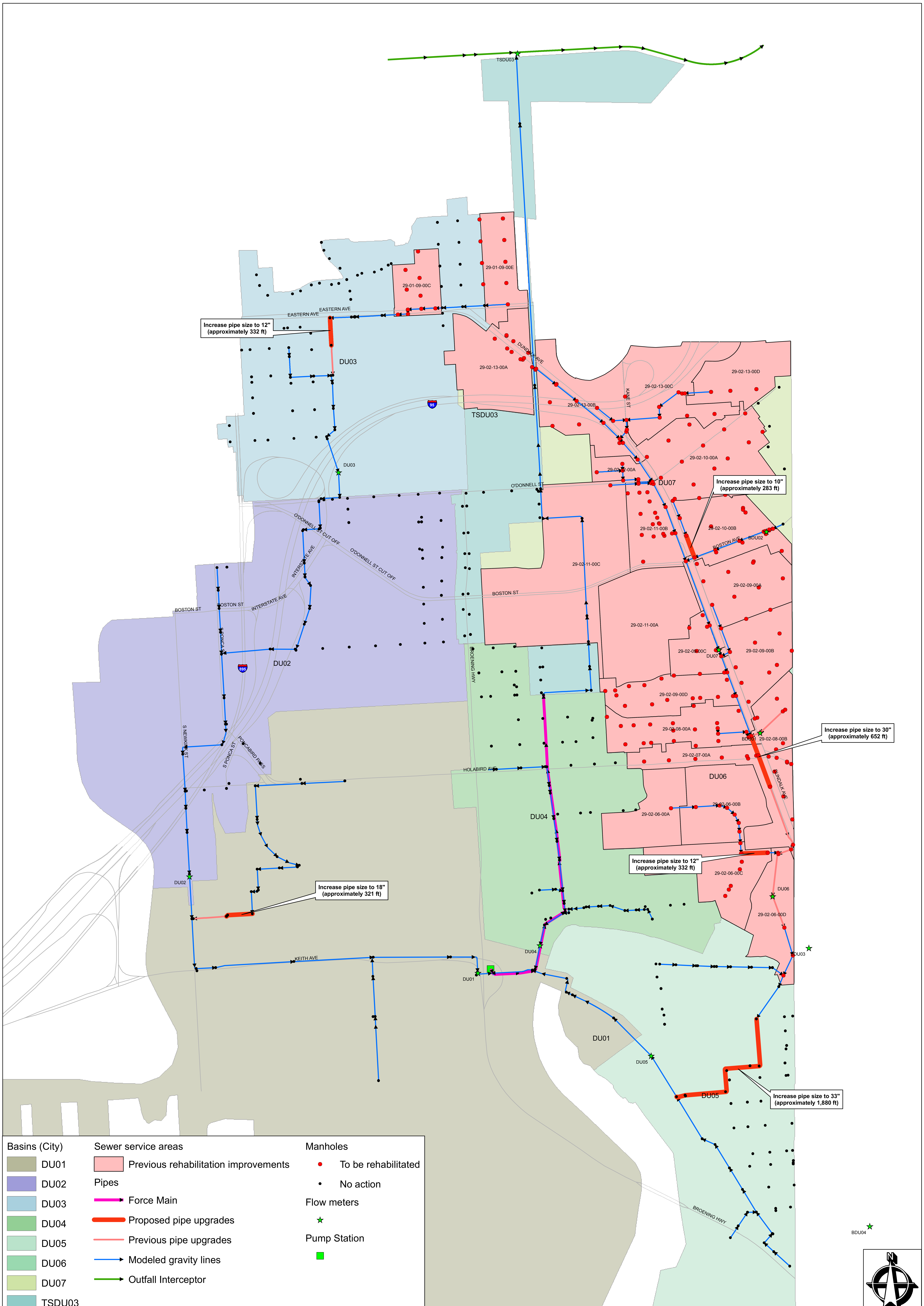
Excellence through Ownership

March 1st, 2010

Scale: 1 inch = 500 feet



Map 5.4.4

CITY OF BALTIMORE

STEPHANIE RAWLINGS-BLAKE
MAYOR

Project 1047 - Dundalk Collection System Evaluation & Sewershed Plan

Dundalk Alternative Analysis (15-Year Storm)

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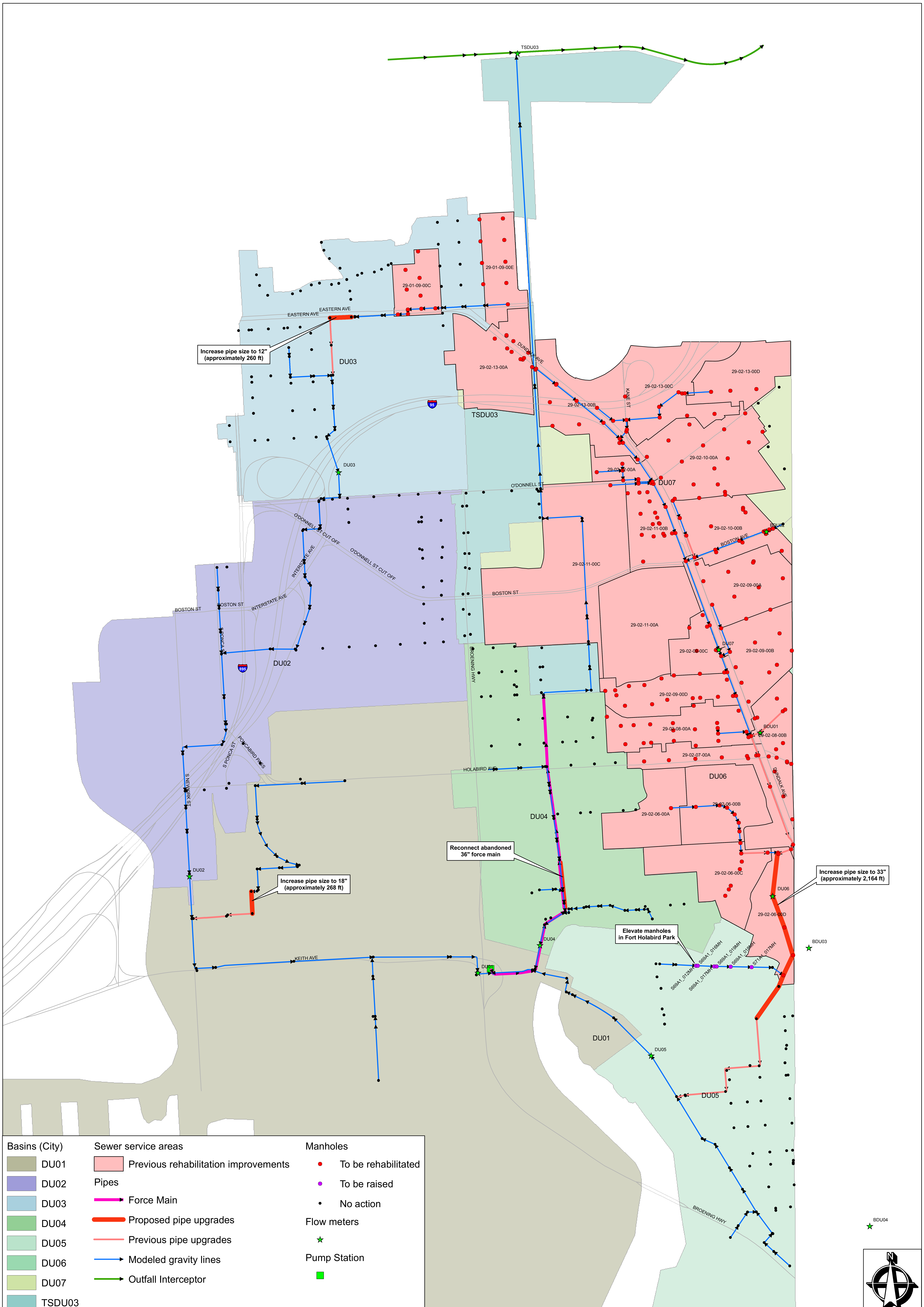
Excellence through Ownership

March 1st, 2010

Scale: 1 inch = 500 feet



Map 5.4.5

STEPHANIE RAWLINGS-BLAKE
MAYOR

Project 1047 - Dundalk Collection System Evaluation & Sewershed Plan

Dundalk Alternative Analysis (20-Year Storm)

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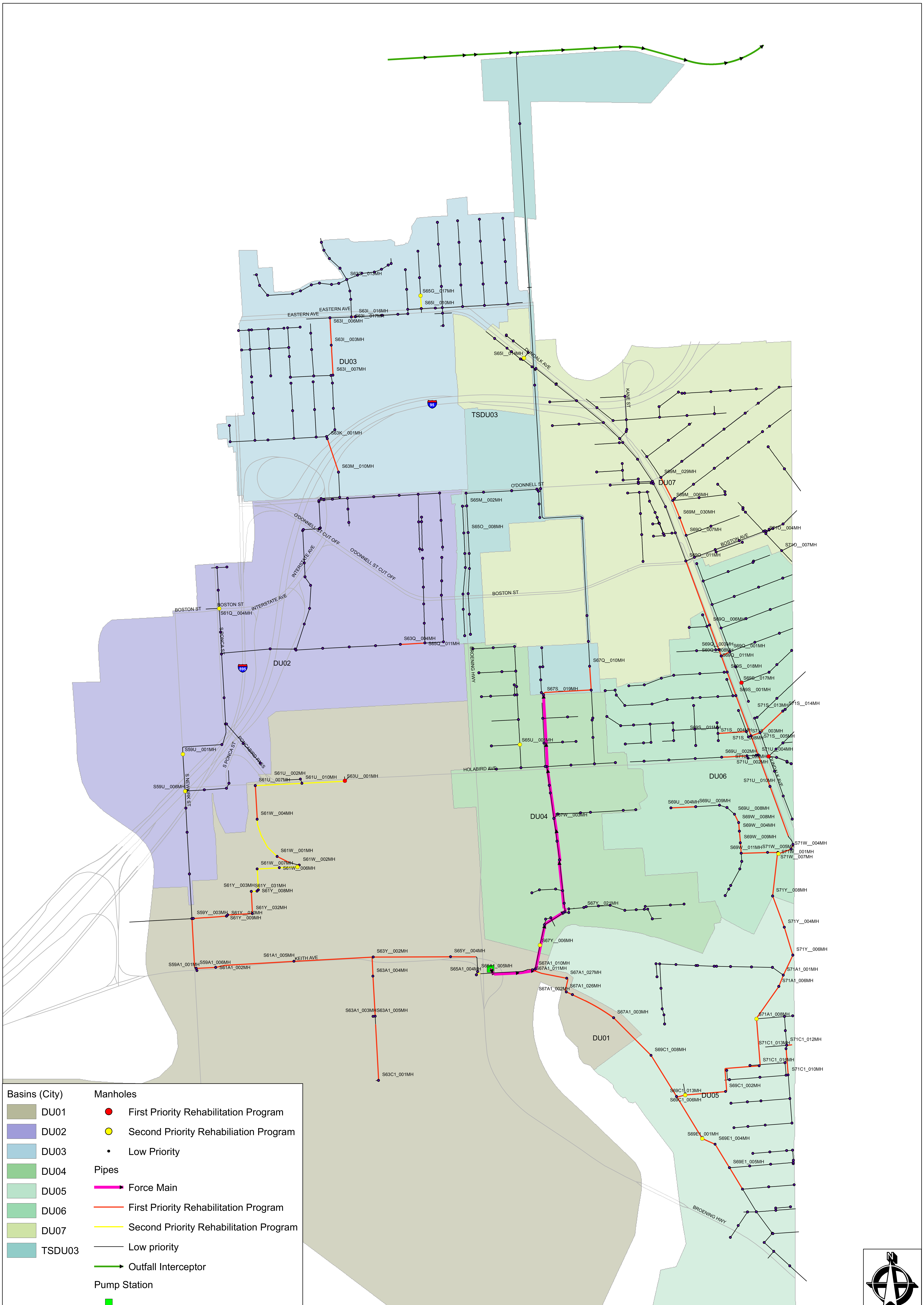
Excellence through Ownership

March 1st, 2010

Scale: 1 inch = 500 feet



Map 7.2.2

STEPHANIE RAWLINGS-BLAKE
MAYOR

Project 1047 - Dundalk Collection System Evaluation & Sewershed Plan

First and Second Priority Manholes and Sewers

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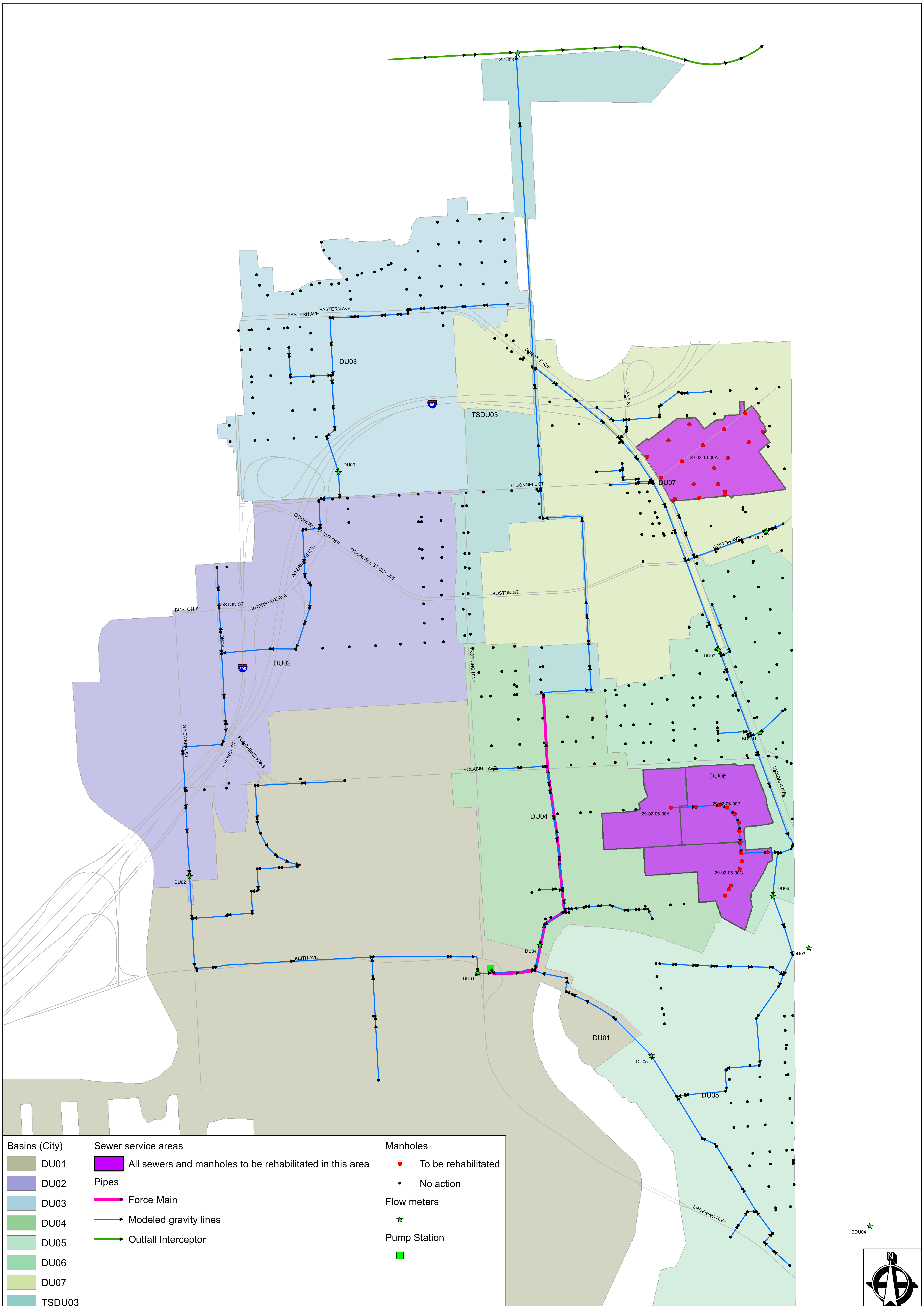
March 1st, 2010

Scale: 1 inch = 500 feet



Map 7.2.3

CITY OF BALTIMORE

STEPHANIE RAWLINGS-BLAKE MAYOR

Project 1047 - Dundalk Collection System Evaluation & Sewershed Plan

Dundalk Recommended 2-Year Hydraulic Improvements

rjngroup

March 1st, 2010

Scale: 1 inch = 500 feet